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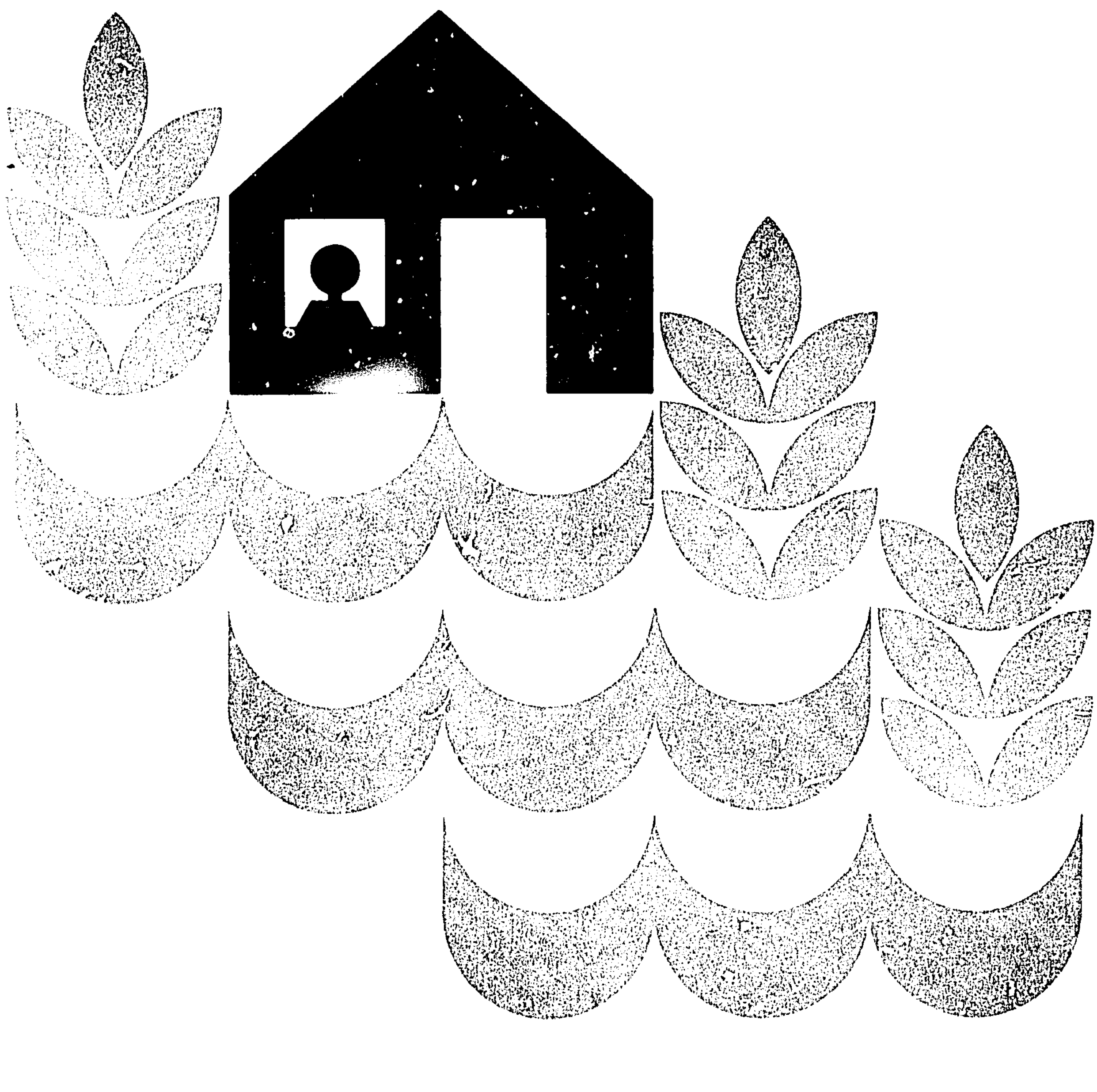
CIRCULAR CONCRETE IRRIGATION TURNOUT: DESIGN AND CONSTRUCTION

HANDBOOK NO. 1

Water Management Synthesis Project



CIRCULAR CONCRETE IRRIGATION TURNOUT: DESIGN AND CONSTRUCTION

Thomas Trout, W. D. Kemper, and Hafiz Sadrul Hasan

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Assistance in the refinement of this manual was given by Carroll A. Hackbart, U.S. Soil Conservation Service; A.R. Robinson, consultant; Kern Stutler, Utah State University; Gary Gerig, Department of Industrial Sciences, CSU; Gil Corey, USAID; and Wayne Clyma, Water Management Synthesis Project Co-director. Their help is greatly appreciated.

FORWARD

Circular Concrete Irrigation Turnout: Design and Construction is the first handbook of what is to be a series of handbooks on technologies for improving irrigation water management around the world.

The purpose of this handbook is to provide the necessary information for the design, construction and use of an irrigation channel turnout. The structure was developed and used successfully in Pakistan. We believe the improvement of farm conveyance channels is an important need around the world, and the successful adoption of this structure, where appropriate, will help in meeting this need.

We would appreciate hearing from you concerning your experiences in using the handbook and structure. Information about other technologies that have been successful under the particular conditions in your country are welcomed also. Additional copies of this handbook are available from the Water Management Synthesis Project.

Our sincere desire is for better water management worldwide in the future.

Wayne Clyma and Jack Keller,
Co-Directors

Water Management Synthesis Project

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CIRCULAR CONCRETE IRRIGATION TURNOUT: DESIGN AND CONSTRUCTION

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SECTION 1

INTRODUCTION

On most of the over 200 million hectares of irrigated land in the world, water is carried from canals, tanks, or wells to individual fields through earthen channels or watercourses. On many of these small irrigation conveyance systems, farmers direct the water through channels by building and breaking earthen dams and cutting holes in the banks with a spade. The result of this process is water loss due to weak, porous channel banks and poor water control, deteriorated channels in junctions where soil is borrowed, and a tired farmer.

Research into the causes of low irrigation efficiencies in Pakistan[2] showed that improved conveyance channel water control structures are very important for improving on-farm water management. Irrigation channel check and turnout structures were developed to reduce channel deterioration and water losses, and to make the irrigator's work easier. The circular concrete turnouts which evolved from this need, shown in Figure 1.1, proved to be successful and have become very popular with the farmers. About 30,000 of these structures had been installed by June, 1981, and more than 300,000 installations are planned in the following three years. This manual describes the development and fabrication of these structures.

No irrigation turnout will be appropriate for every situation. This circular concrete turnout was designed for a specific type of system. For example, it was designed for a rotational distribution system and cannot easily be used to divide water in a branching, constant-flow system. The description of the development of the structure (Section 2) will indicate its use and how irrigation structures for other needs might be developed. Section 5 suggests some alternative designs. *Farm Irrigation Structures* by A. R. Robinson (1982) describes several other types of turnouts as well as gives a general overview of the use and fabrication of small irrigation structures.

If the circular concrete turnout does meet or can be adapted to a particular system's needs, the photographs, drawings, and step-by-step design and fabrication procedures presented in Sections 3 and 4 will help engineers and small manufacturers fabricate and install it.

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[2]Carried out by Mona Reclamation Experimental Project, Water and Power Development Authority; On-Farm Water Management Project, Ministry of Agriculture; and Colorado State University Water Management Research Project, with funding from USAID.

Robinson, A. R. 1982. Farm Irrigation Structures, Water Management Synthesis Project, Colorado State University, Fort Collins, Colorado.

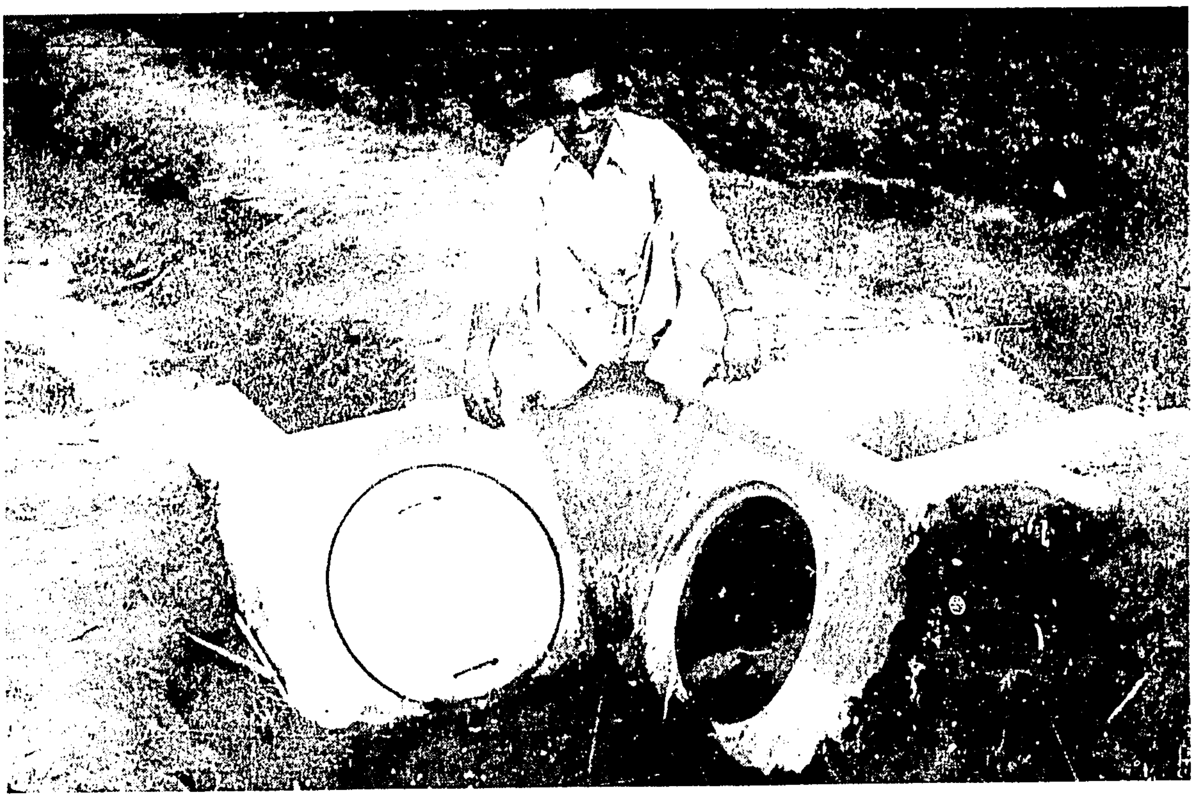


Figure 1.1. Circular concrete irrigation channel turnout structures developed in Pakistan.

SECTION 2

DEVELOPMENT OF CIRCULAR CONCRETE TURNOUTS

The original development of the circular concrete turnout for use in the Indus Basin will be described to indicate the process of designing an irrigation structure to fulfill a specific need, and to point out the important design factors to be considered.

The Need for Improved Control Structures in Pakistan

In Pakistan, the traditional means of directing water through farm level conveyance systems is by building and breaking earthen dams and cutting holes in channel banks. This process results in water losses, deteriorated channels, poor water control, high labor requirements, and disputes between farmers. Whenever earthen check dams are built, soil is borrowed from the adjacent channel banks or fields, causing often-used junctions to become ponds with thin walls, as shown in Figure 2.1. This soil borrowing often creates conflicts with the farmer who owns the adjacent land. Even if adjacent soil isn't borrowed for building dams, it is often saturated from leakage through the low, narrow banks. When the dams are opened, much of the soil erodes away and is deposited in the channel downstream where it must be cleaned out periodically.

The process of building and breaking dams requires several minutes. In the small irrigated basins where total irrigation times are only one or two hours, this time can be a significant portion of the farmer's water turn.

The small basins are irrigated through cuts in the banks. Because of low gradients in many of the systems, two or more cuts are made for each 0.1 to 0.4 ha plot. The result is hundreds of old refilled cuts in a watercourse system - an average of 5 per 100 m of channel. Each cut, like the one shown in Figure 2.2, is a potential leak and weak place that could wash out, especially in clay soils that shrink on drying or in non-cohesive, sandy soils. The potential for washouts and breaches cause diligent farmers to spend much time walking the channels checking for breaks. Also, because of the difficulty in determining whether a break was accidental or purposeful (water stealing), disputes between suspecting farmers are common, and powerful farmers can often "borrow" water at will. All of these factors indicate the potential in Pakistan for reducing water losses, labor inputs, and disputes between farmers with improved water control structures.

Cultivable land in the Indus Basin is more plentiful than water to irrigate. During certain times of the year, water supplies are acutely deficient. Consequently, the marginal value of water tends to be high and a reduction of water losses is economically desirable. Water losses also contribute to waterlogging and salinity problems in many areas. The tight schedule necessary for double cropping results in periods of labor shortage when the value of labor required for irrigation is high. Improved irrigation structures consequently have potential economic benefits from both water and labor savings.

The branching watercourse conveyance systems are operated on a strict turn rotation. Water flows down the main channels and is diverted into each of the branches weekly. Structures installed at these junctions would be used regularly. However, due to the small field sizes (average size 0.2 ha) and the large number of field turnouts required, permanent structures for each field is of questionable economic benefit.

Figure 2.1. A deteriorated watercourse junction with enlarged sections and thin banks due to building and opening earthen check dams.

Figure 2.2. Water leakage from a poorly closed turnout cut.

Therefore, a decision was made to install permanent improved structures at the junctions which are used weekly, but not at individual field turnouts. These junctions are the areas where major channel deterioration occurs. Although canvas dams and siphon tubes would be economical at field turnouts if shared by several farmers, the Pakistani farmers were not willing to cooperatively use such portable structures.

Development of Circular Concrete Control Structures

All of the water that enters a watercourse is used by one farmer at a time and farmers' turns are rotated on a regular schedule. Division of water is seldom done and is of secondary importance. Consequently, control structures which only operate completely open or closed were required.

Average land surface slopes in the Indus Basin are small. Consequently, watercourse channels must be built with small slopes, and the head losses (drop of the water surface level) through structures minimized. Due to the small farm and field sizes, several branches exit from each main channel. Most of these branches require check structures across the main branch to redirect water through the turnouts. Therefore, as water flows to any given field, it passes through several open checks, accumulating part of the individual head losses and making the minimization of these losses especially important.

Likewise, water flowing to a given field will flow past several closed turnouts to upstream branches. Leakage from each turnout cumulatively decreases the flow at the field. Thus, minimizing leakage from each turnout is very important.

Cement, sand, and bricks are readily available in Pakistan and are cheaper than most other construction materials. Concrete fabricators are located in every town and brick masons live in every village. Unlike steel and wood, concrete and brick masonry have practically no reuse value and thus stealing is not a problem. For these reasons, check and turnout designs were adapted to these materials.

Thus, a structure was desired which:

1) need operate primarily totally open or closed,

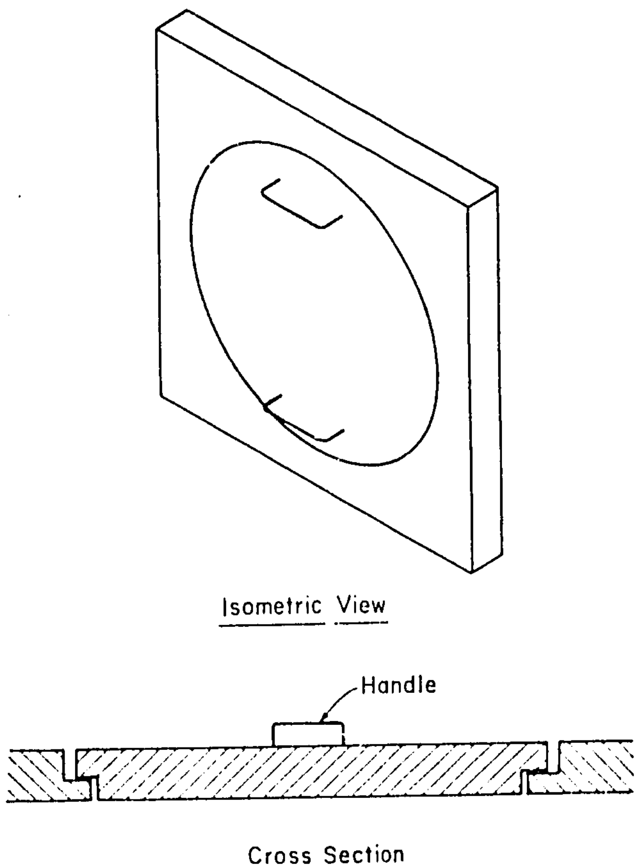
2) minimizes water leakage, especially when used as a turnout,

3) does not cause high head loss, especially when used as a check,

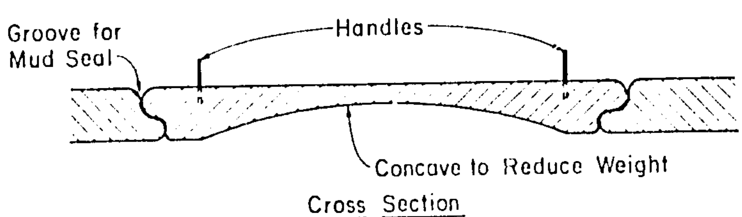
4) can be constructed locally from concrete and/or brick masonry, and

5) is simple to use, durable, and inexpensive to construct and install.

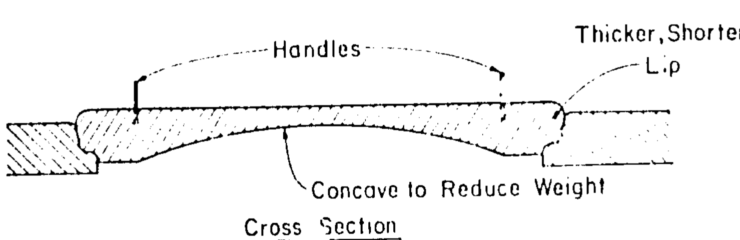
Based on the potential economic benefits, these requirements of the physical system, and the given material preferences, concrete panels with circular lids (shown in Fig. 2.3) set in brick masonry installations were developed to fulfill the control structure needs. Because checks and turnouts in the rotational distribution system function the same, one design was used for both structures. The low head loss requirement for check structures can be attained by using larger diameter gates for checks. Only if the size and weight of the lid becomes unwieldy must special checks be designed. The term "turnout" will be used to describe the structure which is used for both purposes.



a. **Initial design with square sealing surface and one handle.**



b. **Improved design with rounded sealing surface.**



c. **Final desig ith thicker lid lip.**

Figure 2.3. Evolution of circular concrete turnout design.

The circular shape of the turnout lid was initially chosen because round forms for casting the gates could easily be made on widely available lathes. The round lid shape is also structurally strong. Because the structure's freeboard requirement to prevent overtopping is met by the stationary panel rather than the lid, the size (and consequently, weight) of the lid can also be minimized to only that cross-sectional area required for the flow of water.

Experience with the structures revealed an additional advantage of the circular shape. Silt often accumulated on the bottom portion of the sealing surface of an open turnout panel and interfered with the complete seating of the lid, allowing significant leakage. With round lids, this silt can be easily removed or smoothed out by rotating the lid in the panel.

At first, circular lids and frames were cast with simple square sealing surfaces, as shown in Figure 2.3*a*. Experience with this design showed that chipping of the square corners was a problem. The design was consequently modified by rounding the sealing surface, as shown in Figure 2.3*b*. This improvement not only reduced the chipping problem but also distributed the impact force during closing evenly along the whole of the sealing surface, reducing breakage of the lid and panel. The rounded lip also allowed the lid to slip easily into the panel. The groove resulting from the rounding at the front of the gate allowed farmers to apply mud to the joint to stop any water leakage, although refinement of the fabrication process made this extra effort unnecessary in most cases.

The biggest advantage of the circular shape and rounded sealing surface was realized during the improvement of the fabrication of the structure. Early panels and lids were cast separately from individual forms. However, the precision required to achieve a perfect fit between the lid and frame could not be achieved and the turnouts leaked. Rubber gaskets were attached to the lids of some turnouts to stop the leakage. Experience showed that this was not a desirable solution because the gaskets occasionally loosened, deteriorated over time, and/or were taken by village boys to be used in sling shots. A turnout with a removed or bad gasket leaked much more than one with no gasket.

After some experimentation, the fabricator discovered that he could achieve a leak-free fit between the lid and frame by using the panel as the form in which he cast the lid. He cast the panel with a precision metal form, let it harden for a day, applied oil to the mating sealing surface, and cast the lid directly in the panel. The oil prevented the lid concrete from bonding to the panel, and the lid could be separated from the panel after hardening.

The sealing surfaces were still slightly rough and the fit very tight, so after the curing, the lid was "ground" in its panel by turning it back and forth while pouring water over it. This grinding loosened the fit, smoothed the sealing surfaces, and insured that the lid would fit in the panel in any position. The result was a totally leak-free, concrete-on-concrete seal.

Because of the density of concrete, the weight of the lids of larger gates made them difficult to handle. This weight was reduced by about one-third by casting the lids over an inverted bowl, resulting in the concave shape shown in Figure 2.3*b*. Due to the inherent structural strength of the round shape, this reduction in concrete does not significantly reduce the strength of the lid.

Initially, one handle was placed in the center of the lid as illustrated in Figure 2.3*a*. Experience soon showed that the heavy lids were easier to handle with two handles near the edges. This change made it much easier to open the lid against the hydrostatic pressure of the water in a full channel, and to rotate it once in place to insure a good seating and to remove silt. The double handles also allowed for the use of a lever, such as a board or metal rod placed through the handles, to open the gate against the hydrostatic pressure. Such a lever with a hook on the bottom could be used to open or seat a large lid from above the structure.

Once a leak-free gate was developed, additional work involved improving the durability of the turnout. The most common breakage problem involved chipping and breaking the outer lip on the lids. The lip was redesigned and strengthened by making it thicker and shorter, as shown in Fig. 2.3c.

It was decided that the critical parts, the lid and panel, would be precast at a central location where standard methods could be specified and high quality insured. The panels were cast in a shape which could be easily transported to field sites and installed into structures appropriate for each situation. Once a market was established, concrete contractors in regional towns were willing to make the panels and lids to the required specifications.

The specifications included not only dimensions, but also strength and durability. Concrete mixes, cement water ratios, and reinforcement were specified; as were mixing method, vibration, and curing under water for at least seven days. A sample panel from each lot was broken to insure that the concrete was sufficiently strong.

As a result of this quality control, present estimates are that less than 10% of the lids or panels will need to be replaced each year. Most of this breakage is caused by the farmer's misuse of the structures. His financial investment in the structures would probably reduce abuse and breakage.

This evolutionary development resulted in an inexpensive, durable, water control structure adapted to the needs of Pakistani irrigators. The gate has very low leakage--much lower than expected from a concrete-on-concrete seal. It is structurally strong and can be made in any size to achieve a required head loss. It is locally made from locally available materials that have little likelihood of being stolen, and from a material which has an indefinite life in water. The structure is simple to use, and is designed to minimize the difficulties with its weight. It is also specifically designed for a rotational irrigation system and cannot be used to accurately divide flows or regulate heads.

The development process involved the patient interaction of the farmer, the fabricator, and the engineer. Only when the engineer understood the practical possibilities and limitations of the construction materials and processes, and only when the fabricator went to the field to learn the farmer's needs and to test his products, was real improvement possible. Through these three working together to build and test dozens of designs, viable turnouts were developed, and are continuing to be improved.

SECTION 3

FABRICATION OF CIRCULAR CONCRETE TURNOUTS

The circular turnouts, as shown in Fig. 2.3, are composed of a panel and a round lid, both cast in reinforced concrete. The critical portion of the structure is the sealing surface beween the lid and panel. This surface must be precisely shaped and smoothed to insure against leakage, and durable to reduce chipping and breakage. This surface is cast in mortar to prevent the protrusion of aggregate. Figure 3.1 shows the recommended dimensions for the sealing surface. As is indicated, larger diameter turnouts should be thicker to maintain adequate strength.

The fabrication process involves preparing the required forms and the reinforcement rod, mixing the concrete, casting the panel, casting the lid in the panel, curing the concrete, and grinding the sealing surface.

Preparing the Forms

Five forms plus a flat, level surface are required for casting circular concrete turnout panels and lids. These are:

1) a panel outer form,

2) a separator ring,

3) a panel ring form,

4) a convex plate and wooden disk, and

5) a lid ring form.

Figures 3.2 and 3.3 illustrate these forms and their placement. Of the five, only the panel ring form is of critical shape and dimensions. This form determines the shape of the sealing surface of the panel.

The panel outer form is simply a box or frame which contains the panel concrete and determines the outside dimensions of the panel. It can be constructed of wood or metal. The outside panel dimensions, and thus the form inside dimensions, should be determined by the type of installation and the difficulty and type of transport to the site. For example, if the turnout is to be set into a brick masonry installation structure, the panel should be sized to fit conveniently into the masonry. The panel should also include sufficient freeboard at the top to prevent overtopping and may be extended at the bottom and/or sides to serve as a buried cutoff wall. If transport to the site is difficult or costly, the size of the panel should be minimized to reduce weight and transport cost. The width of concrete in the panel should not be reduced to less than 10 cm at any point or breakage in transit could become a problem. The height of the form should be equal to the desired thickness of the panel.

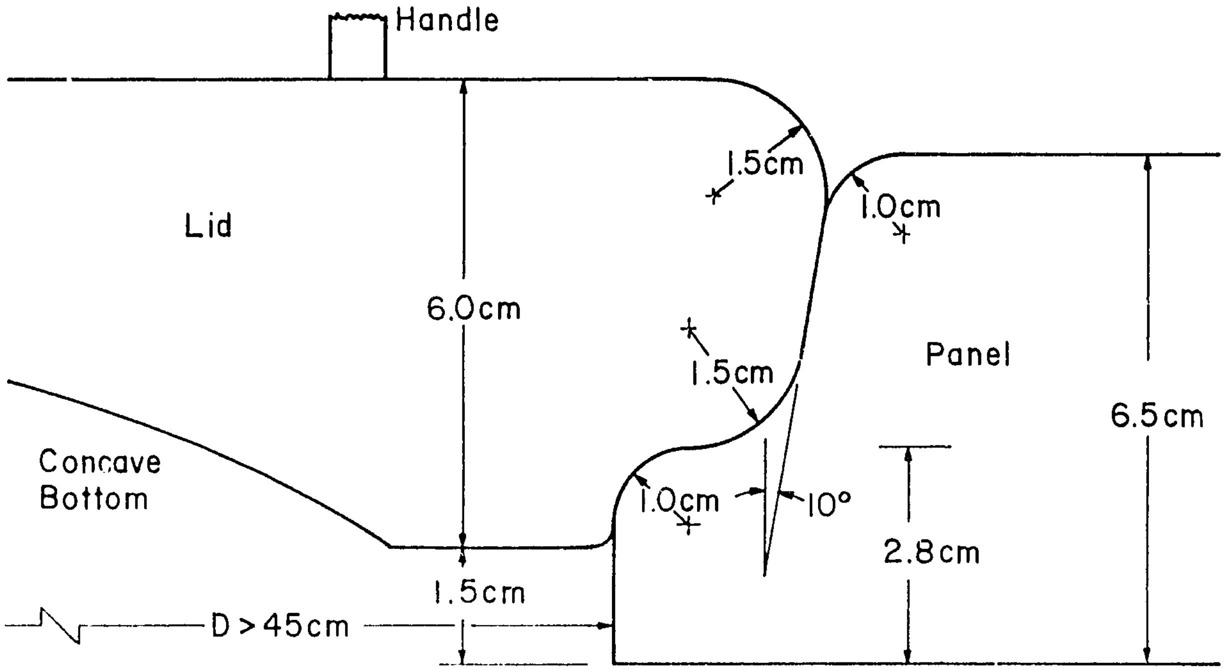
The separator ring separates the concrete of the panel from the mortar which is used on the sealing surface. It should be sized such that 2 to 3 cm of space is left between it and the panel ring form. By making the ring conical in shape as shown in Figure 3.2, the volume of mortar required is reduced, the removal of the form is easier, placement of the panel reinforcement rod is easier, and the strength of the structure is increased.

Such a conical form can be made by cutting a curved strap of thin sheet metal 6 percent wider than the desired panel thickness, t (cm), with a length, l, of:

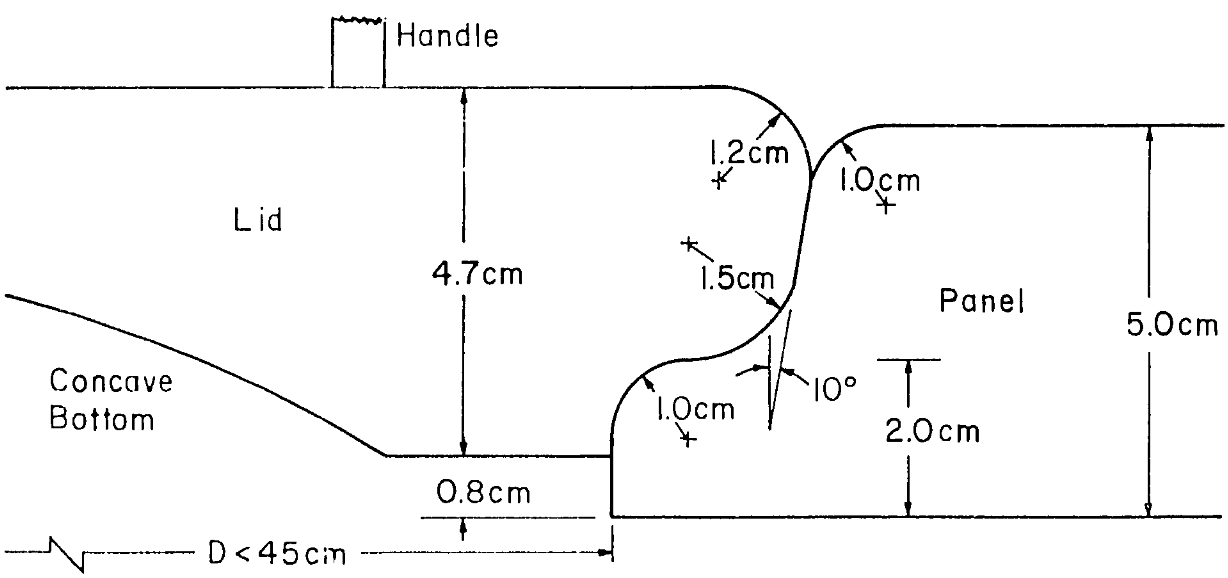
$$l \text{ (cm)} = 3.14\,(D + 0.7t + 4) + 8 \qquad (1)$$

where D is the panel opening diameter (cm). The radius of the outside curve of the strap, R, should be:

$$R \text{ (cm)} = 1.46\,(D + 0.7t + 4). \qquad (2)$$



a. Diameters Larger than 45cm



b. Diameters Smaller than 45 cm

Figure 3.1. Full scale drawings of the sealing surface cross sections for circular concrete turnouts.

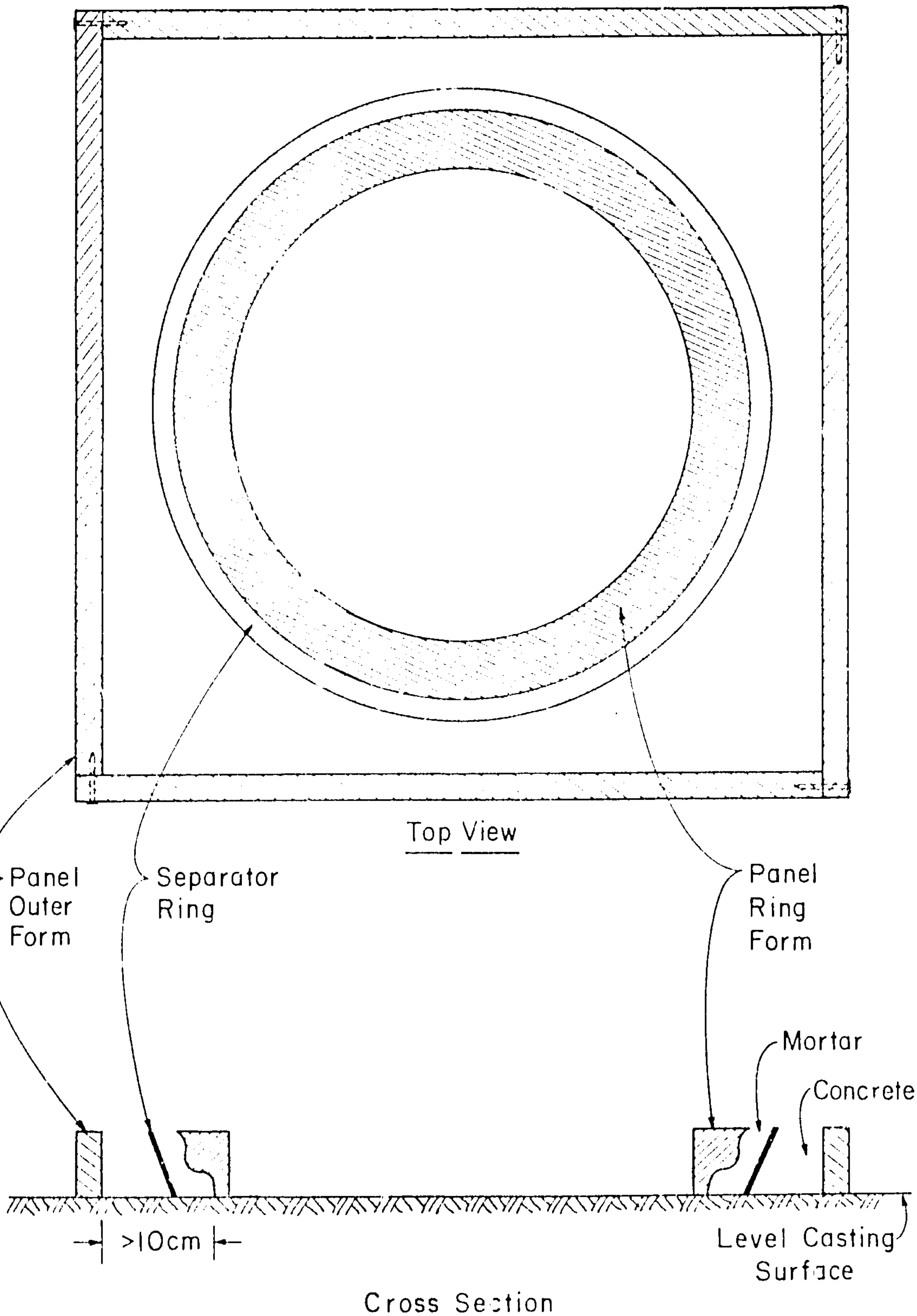


Figure 3.2. Forms required for casting circular concrete turnout panels.

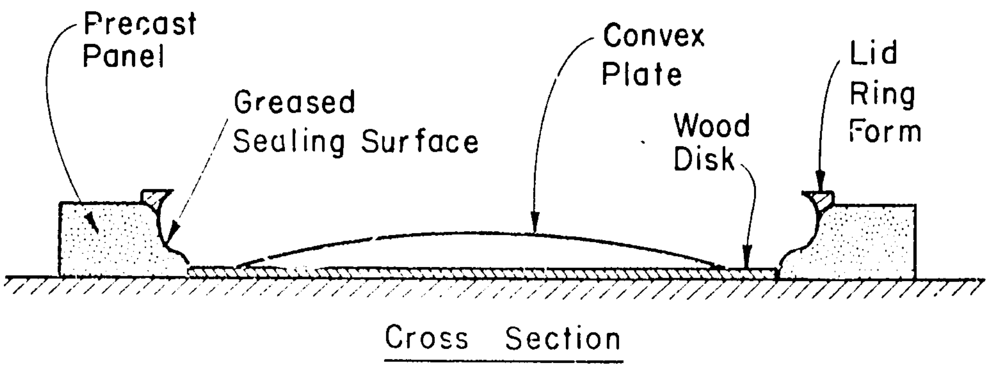


Figure 3.3. Forms required for casting circular concrete turnout lids.

This will result in a conical form with a 20° slant from vertical, a diameter at the bottom 4 cm larger than the panel opening diameter, and an 8 cm allowance to overlap the two ends. Figure 3.4 illustrates such a strap and Table 3.1 lists strap dimensions for different size turnouts. Sheet metal can often be saved by joining several shorter curved straps into the longer one required.

The panel ring form should be cast from mild steel or aluminum (to reduce weight) and then machined in a lathe to the required diameter and dimensions. This ring will have an outer surface shape similar to the desired outer surface of the turnout lid, and will look like a lid with the center removed.

Figure 3.5 shows ring form cross sections for the turnout dimensions shown in Figure 3.1. The lip at the top of the form rounds the edge and creates a groove at the front of the panel. The thickness of the ring should be sufficient to insure rigidity without being too heavy to handle. A thickness of 1.5 cm at the narrowest part (bottom) should be sufficient. The inner ring surface can be tapered upward, as shown by the dashed lines in Figure 3.5 to reduce the weight.

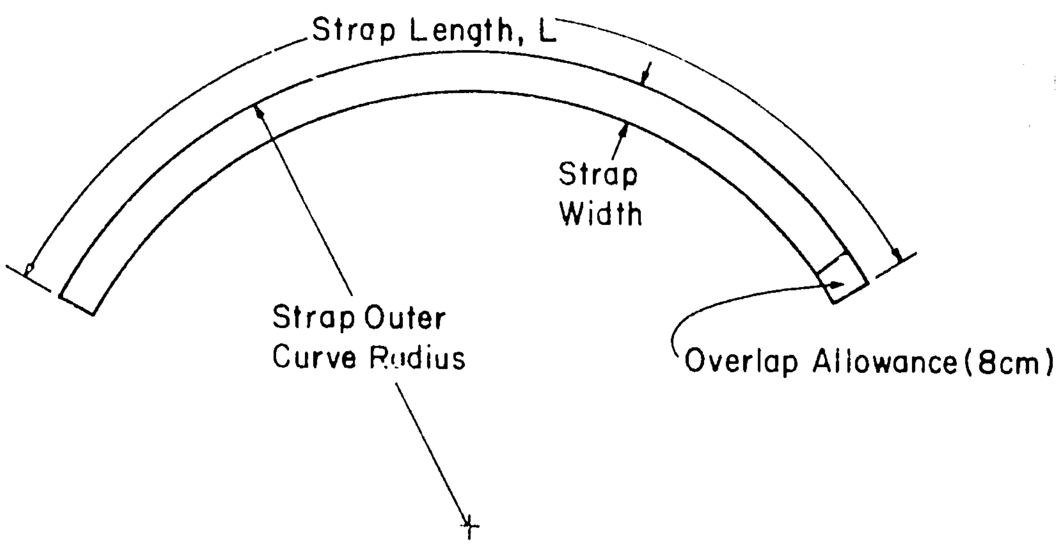


Figure 3.4. Definition sketch for sheet metal strap used to make the separator ring.

Table 3.1. Strap shapes to make conical separator rings with 8 cm overlap allowance at the end.

Turnout Diameter (cm)	Panel Thickness (cm)	Strap Width (cm)	Strap Length (cm)	Strap Outer Curve Radius (cm)
30	5.0	5.3	126	56
35	5.0	5.3	142	62
40	5.0	5.3	157	69
45	6.5	6.9	176	78
50	6.5	6.9	192	86
55	6.5	6.9	208	93
60	6.5	6.9	223	100

Either a full wooden pattern, or a simple sheet metal pattern shaped like the cross sections shown in Figure 3.5 can be used to cast the ring. The cross-sectional pattern, when attached to a metal rod of the proper length and rotated in a circle in the casting sand will create the proper shaped mold. Either pattern must be increased in size 0.5 cm along the outside surface to allow for shrinkage and machining of the casting. This allowance is shown by dashed lines in Figure 3.5.

Once the casting is cool, the outside surface should be machined in a lathe to the proper shape. This shape can be checked by a sheet metal pattern shaped like the desired panel sealing surface cross section (see Fig. 3.1). Handles should be attached to the top of the finished ring to make it easier to use.

To increase the interchangeability and thus the replaceability of turnout lids, all panel ring forms of the same size should be made precisely the same shape and diameter. This implies that one shop should make all forms of a given size from one pattern, and all turnout fabricators must then buy their forms from the authorized maker.

By casting the turnout lid over a convex plate or inverted bowl, its weight will be reduced. These plates should be about 2½ cm thinner in the center than the total lid thickness, or about 3½ cm thick for the large diameter turnouts and 2½ cm thick for the smaller diameters. The diameter of the plates should be about 6 cm less than the turnout opening diameter. The plates can be made from pounded sheet metal in the same way metal bowls are made, or they can be cast in plaster and then coated by a substance which will not adhere to concrete. The convex plates can then be attached to the center of round, flat wooden disks of 1.5 cm thickness for large diameter or 0.8 cm for small diameter turnouts to reduce lid thickness at the edges. Figure 3.6 gives dimensions for these plates and disks.

The final form required is a form to shape the top of the lip of the lid. The form contains the lid concrete until it hardens and results in rounded corners and a groove between the lid and panel. Figure 3.7 gives shapes and dimensions for lid ring cross-sections for the two turnout cross-sections shown in Figure 3.1.

The cross-sectional shape of the lid ring form is not critical. It can be cast and machined on a lathe as the panel ring form was made, or it can be fabricated from sheet metal or straight stock such as angle iron. It must be sufficiently rigid to maintain a circular shape.

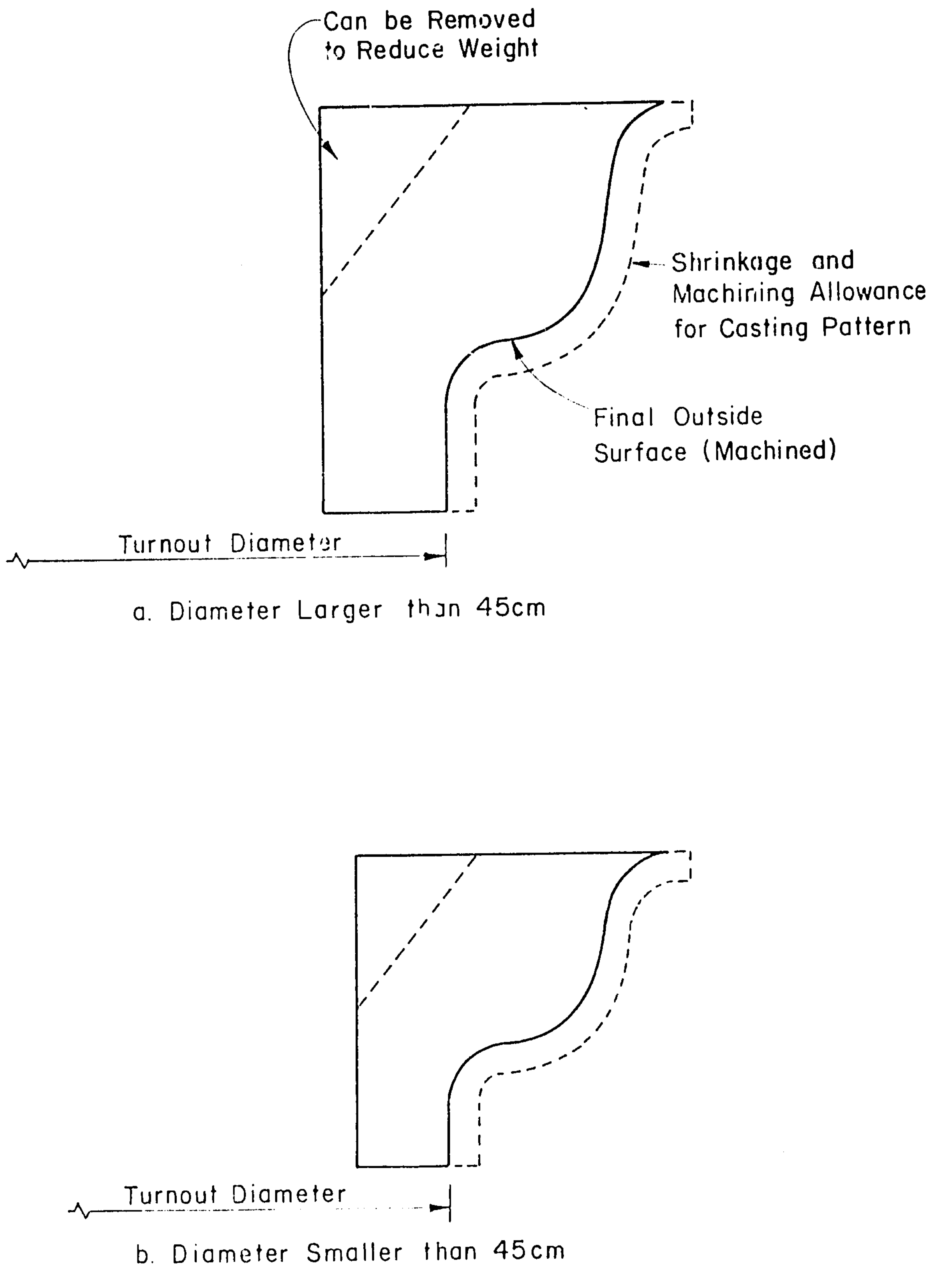


Figure 3.5. Panel ring form cross-sectional shapes.

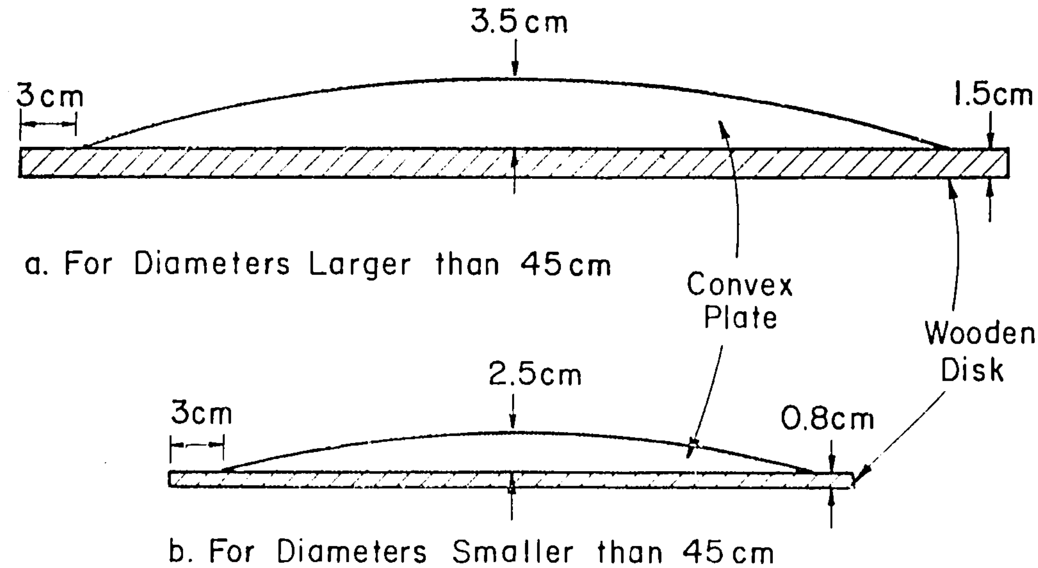


Figure 3.6. Cross-sectional view of convex plate and wooden disk on which turnout lids are cast.

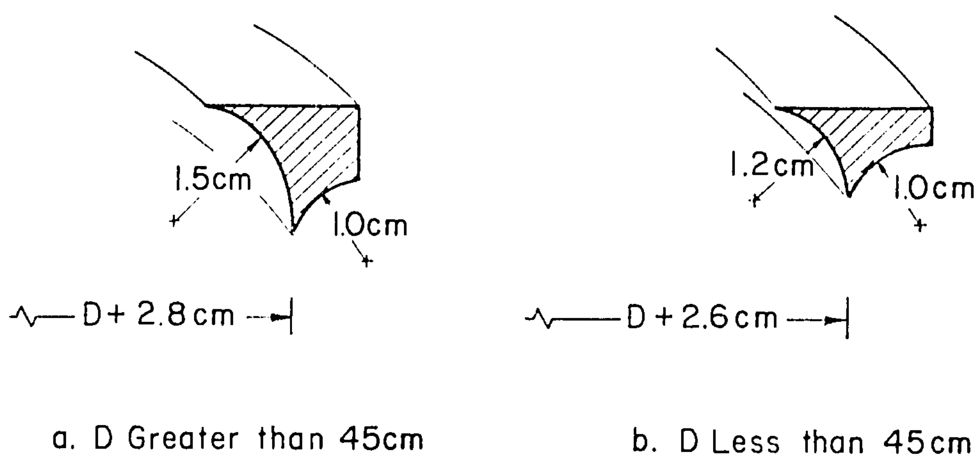


Figure 3.7. Cross-sectional shape of lid ring form.

Preparing the Concrete

To increase durability, a rich concrete mixture should be used. A cement:sand:gravel ratio of 1:2:3 (volumetric) is recommended. The sand and gravel should be clean (without fine particles such as silt). Dirty sand or gravel must by washed. The sand and gravel should be evenly graded. Gravel aggregate size should not exceed 1.5 cm for the larger diameter turnouts and 1.0 cm for the smaller size turnouts.

Clear water with low salt content should be used. As a general rule, water used in concrete should be drinkable. As dry a mixture as can be easily placed in the forms should be used, since the drier the mixture, the higher strength the concrete. The water:cement ratio should not be more than 0.5:1 or about 25 liters (6.6 gal) of water per 50 kg bag of cement to achieve adequate strength concrete.

The concrete must be mixed in a mechanical mixer for at least three minutes and should be mixed no more than 1½ hours (1 hour in hot climates) before it is poured. The mixed cement should not be left in the hot sun or it will begin to harden. Appendix I gives additional instructions on choosing, proportioning and mixing concrete materials.

The mortar used along the sealing surfaces should have a rich cement: sand ratio of 1:1. It also should be made with clean sand and water, thoroughly mixed as dry as is workable, and not left to stand longer than 1½ hours under moderate temperatures.

Casting the Panel

The panel outer form and separator ring should be placed on a hard, level surface. Newspaper laid on the casting surface before placing the forms will prevent the concrete from sticking to the surface. A light coat of grease or oil on the forms will aid their removal, if sticking is a problem.

Two bars of preformed 3 mm (1/8 inch) reinforcement rod (rebar) should be placed between the two forms. The rebar should follow the outside perimeter of the panel about 2 cm inside the outer form as shown in Figure 3.8. The rebar should be pre-bent to the proper shape and wired or welded together, as shown in Figures 3.9 and 3.10.

The concrete is then poured between the two forms and worked into place (Fig. 3.11). As soon as the concrete will roughly maintain its shape, the separator ring should be removed. If the concrete mixture is dry enough, this can be done immediately. Do not allow the concrete to set up too long or the mortar will not adhere to it well.

After the separator ring is removed, place two rebar rings, shown in Figure 3.8, on the inside edge of the concrete and plaster over with mortar (Fig. 3.12). When sufficient mortar has been applied (the proper amount will be determined with experience) place the panel ring form on the panel and work it, by rotation, down until it rests on the bottom surface (Fig. 3.13). No spaces should remain between the ring form and mortar or the ring must be removed and more mortar added. Remove excess mortar around the form and vibrate the concrete to remove air bubbles, increase the density and strength of the mixture, and improve the bonding between the mortar and concrete. The vibration can be done on a platform vibrator (a platform which vibrates at a high frequency) or with a flexible shaft probe vibrator (shown in Fig. 3.17).

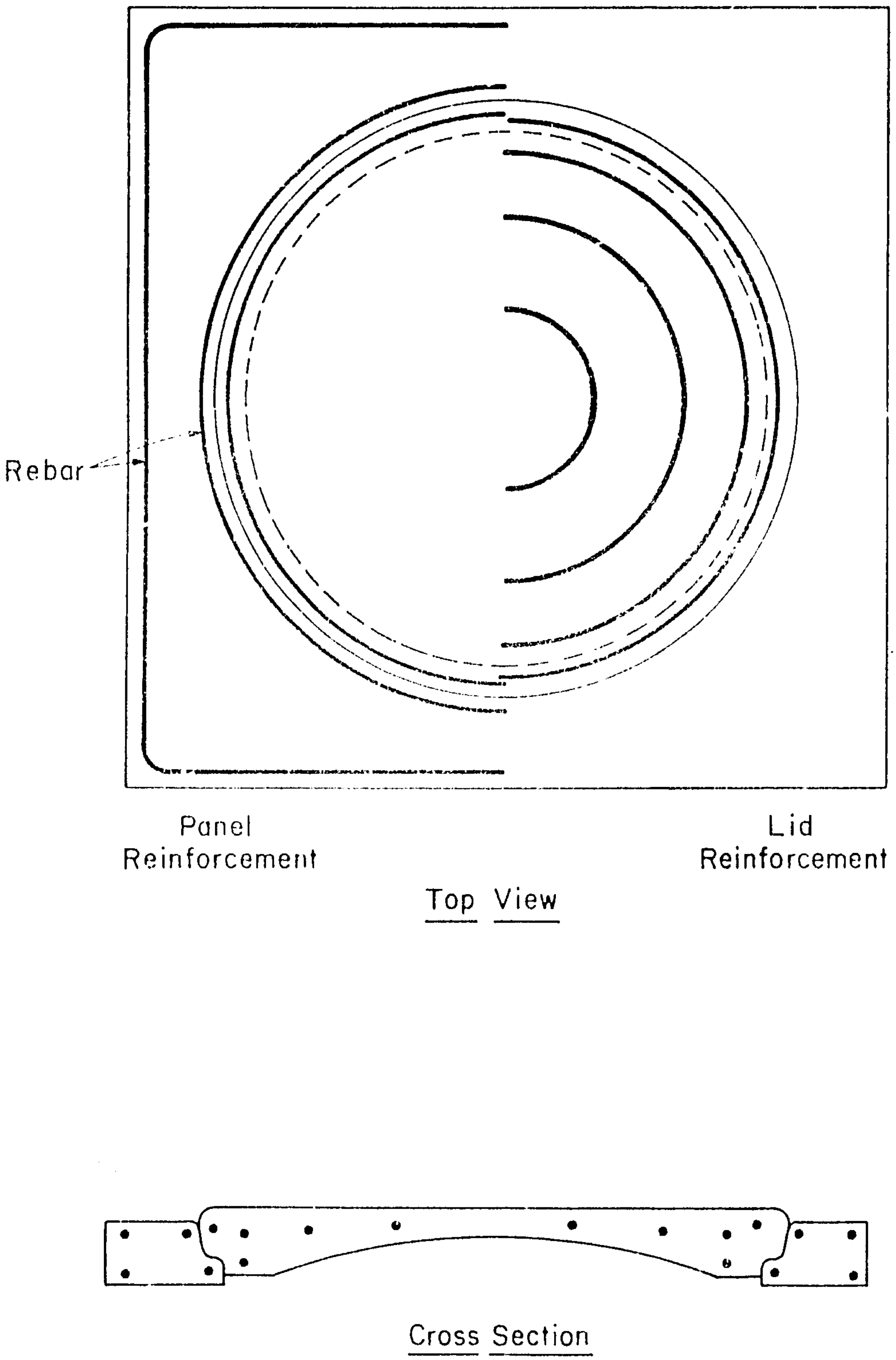


Figure 3.8. Reinforcement rod placement in the circular concrete turnouts.

Figure 3.9. Shaping the reinforcement rods for the panel.

Figure 3.10. Welding the reinforcement rods for the panel.

Figure 3.11. Placing the concrete between the outer panel form and separator ring. Notice the newspaper laid below the forms and the rebar placement.

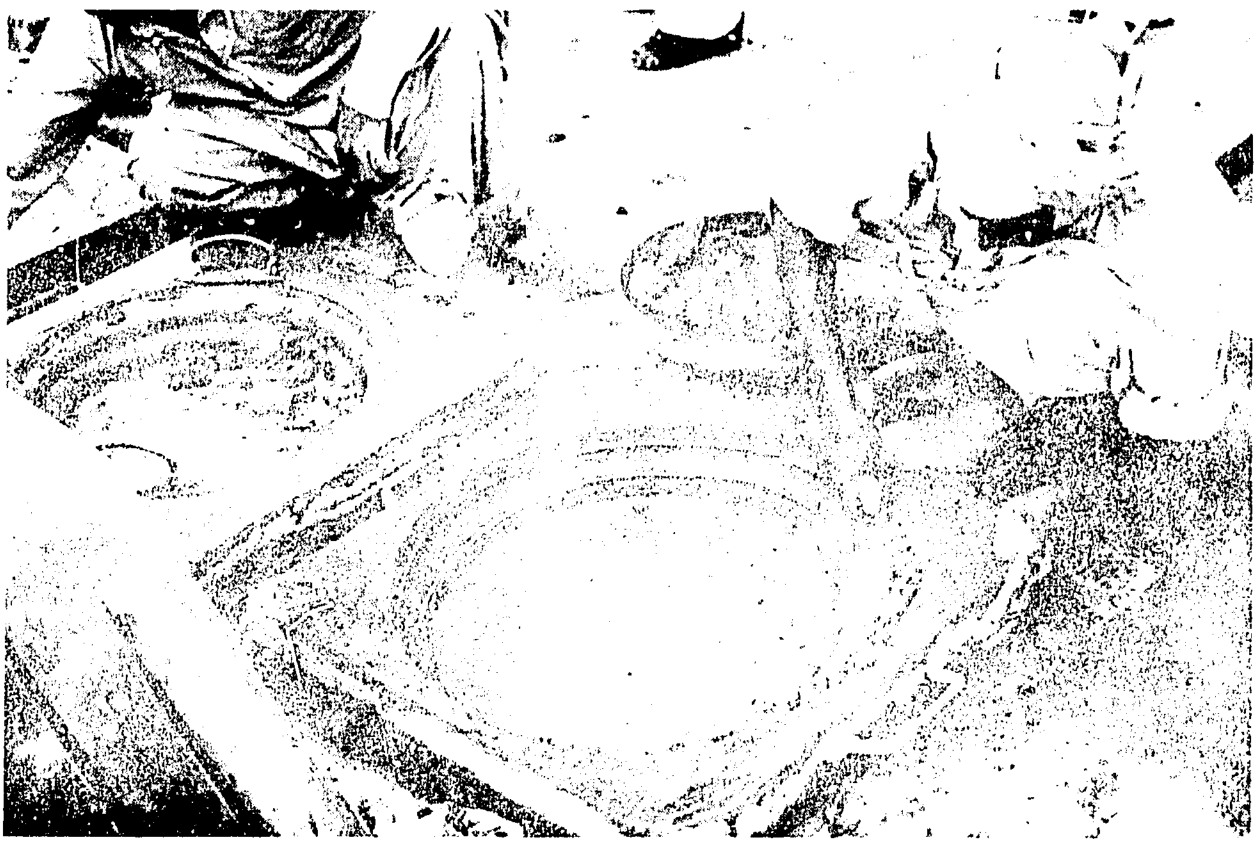


Figure 3.12. Placing the panel rebar rings and plastering the sealing surface with mortar.

Figure 3.13. Placing the panel ring form in the panel to shape the mortar. Notice the handles on the ring.

Normally, the forms should not be removed for 24 hours until the concrete has partially hardened or set up. However, because of the expense of the ring forms, it is desireable to reuse them as often as possible, and thus to remove them as soon as possible. If the vibrated mixture is sufficiently dry, the ring can be removed after a few minutes without the mortar settling or sluffing. This process can be aided by sprinkling cement on the surface of the panel to absorb any excess water. The ring must be removed very carefully to avoid disturbing the shape of the sealing surface, or leaving the surface rough. A twist of the form will make removal easier. As soon as the ring is removed, it can be wiped clean and reused.

The freshly cast panel must remain undisturbed for the next 24 hours while it begins to harden. The fresh concrete must not dry out if the cement is to set up properly and reach its potential hardness. The initial 48 hours are critical in this curing process. The panels should, therefore, not be set in direct hot sunlight; and in hot, dry climates, must be sprinkled often and/or covered with moist cloth or a mulch such as straw to retard evaporation.

Casting the Lid

After the panel has initially hardened (about 24 hours), the sealing surface should be coated with a light layer of used motor oil, as shown in Figure 3.14. The oil will allow fresh mortar to be placed against the sealing surface without adhering. Let the oil soak in for a short time and wipe off the excess oil to insure that the excess does not cause cavities on the lid sealing surface. The wood disk and convex plate can then be placed in the center of the opening. If the plate is made of porous material, it must also be oiled.

Apply a 2 or 3 cm layer of mortar to the panel sealing surface. Embed two rings of rebar in the mortar (see Fig. 3.8). Be sure the rings are not closer than 1 cm to the surface of the panel. Pour the remainder of the lid half full of concrete and place the remaining 3 rebar rings in the concrete (Figs. 3.15 and 3.16).

Place the lid ring form on the panel. Then fill the panel and ring form level full with concrete and vibrate the mixture as shown in Figure 3.17.

After vibration, the handles should be inserted into the lid about 6 cm from the outer edge. The handles can be made from 1 cm diameter rebar cut in about 35 cm lengths and bent in a U-shape, as shown in Figure 3.18. The bottom 2 to 3 cm of each leg of the handle should be bent towards the center of the lid to help anchor it. The two handles can be pushed and tapped into the lid with the assistance of a small hammer, as shown in Figure 3.19. The handles should extend about two-thirds the way into the lid.

An alternative means of installing the lid handles is to weld or wire them to the rebar and thus place them with the rebar. The concrete is then poured around the handles.

After casting is compete, the lid should be kept moist for curing as has been done with the panel. After the lid has hardened sufficiently to move without danger of damage, (24 hours in a hot climate, up to 48 hours in cool weather) the panel and lid should be submerged in a pond of water for at least 7 days, and preferably 14 days (Fig. 3.20). Submerged curing will greatly increase the strength of the concrete.

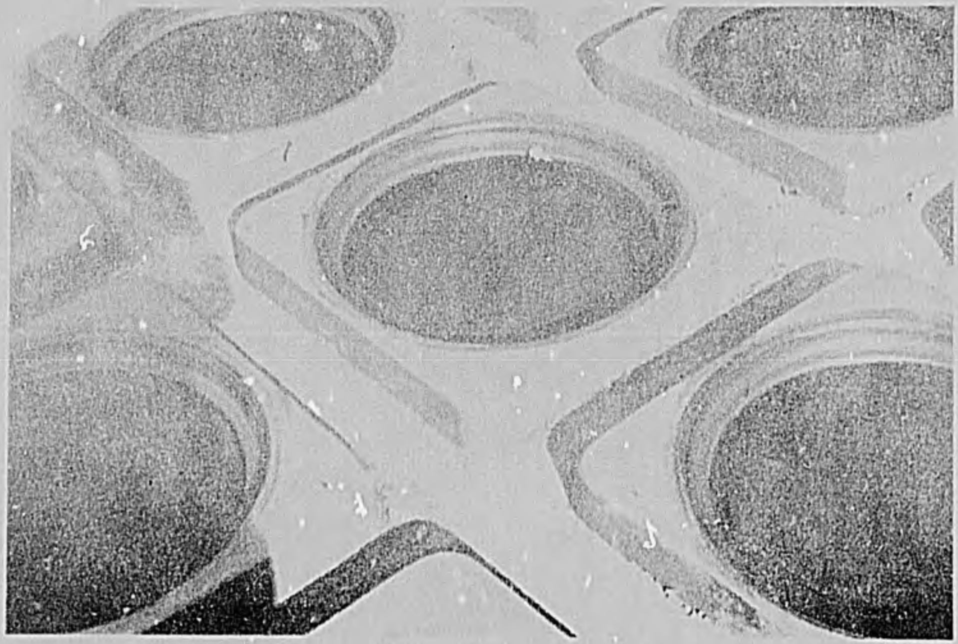


Figure 3.14. Oiled panels with the convex plate inserted, ready for casting the lids.

Figure 3.15. Pouring concrete for the lid.

Figure 3.16. Placing the lid rebar.

Figure 3.17. Vibrating the lid with a probe vibrator.

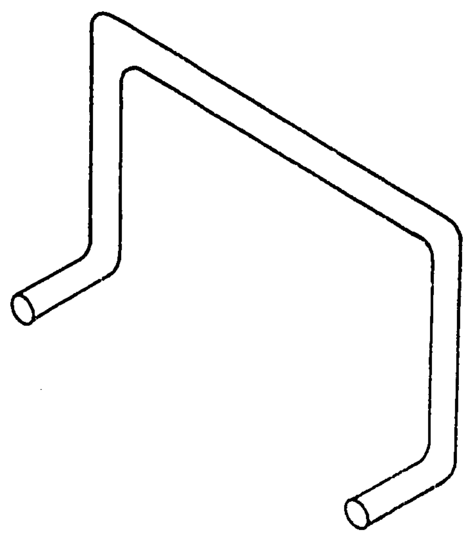


Figure 3.18. Handle shape for the turnout lid.

Figure 3.19. Inserting the handles into the lid. Notice the lid ring form.

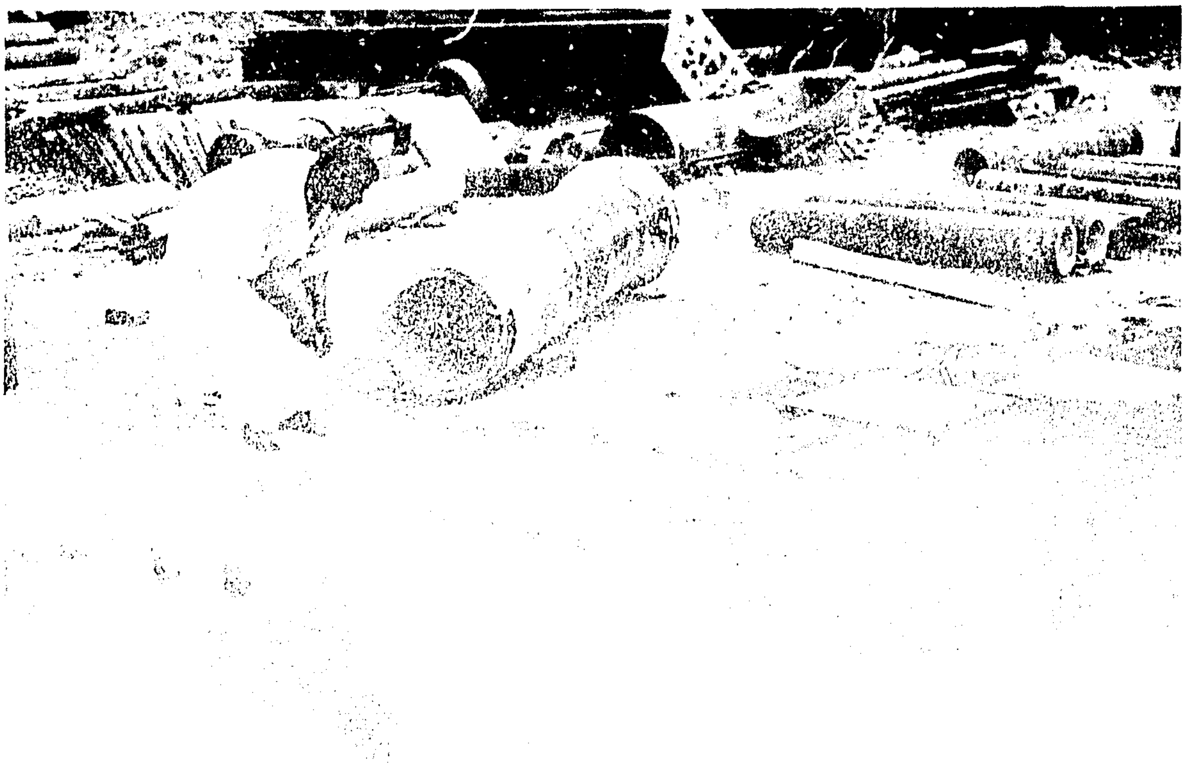


Figure 3.20. Curing the panels and lids in a pond for at least seven days.

After curing, the lid can be separated from the panel by tapping from the back with a rubber mallet. If loosening the lid is difficult, the removal can be tried after initial hardening, but before curing, and the panel sealing surface can be oiled better.

After the structure is cured and the lid removed, the sealing surfaces of the lid and panel should be ground smooth. This is done, as is shown in Figure 3.21, by rotating the lid back and forth in the panel while slowly pouring water over the lid. The water lubricates the sealing surface to make turning easier and to wash away the dust which results from the grinding. If the lid turns unevenly in the panel, this indicates that the panel ring form is warped or otherwise out-of-round and must be replaced.

The purpose of casting the lid and panel in two steps with mortar next to the sealing surfaces is so that large aggregates do not protrude from these surfaces and interfere with the grinding and smoothing process. If an alternative method can be developed which accomplishes the same smooth surface, or experience shows that the aggregate does not cause problems, the structure could be cast entirely of concrete, simplifying the process and reducing both labor and material costs.

After the casting and grinding process, the lid and panel should have a precisely mated, smooth, and leak-free joint which will remain sound for several years with normal use. Once the fabrication process is established and standardized, all lids made in panels cast from the same mold should be interchangeable, and if the mold making is standardized, all lids should fit in any panel of the same diameter. This standardization is strongly recommended because:

1) lids and panels otherwise need to be marked in pairs and always transported and used together,

2) adjoining turnout and check structures can share the same lid, and

3) if a lid breaks (which is the most common type of breakage), a replacement lid can be purchased without needing to remove and replace the panel.

The turnout panels and lids are now ready to be transported to the field sites for installation (Fig. 3.22).

Figure 3.21. Grinding smooth the sealing surfaces of the lid and panel by rotating the lid in the panel while pouring water over it.

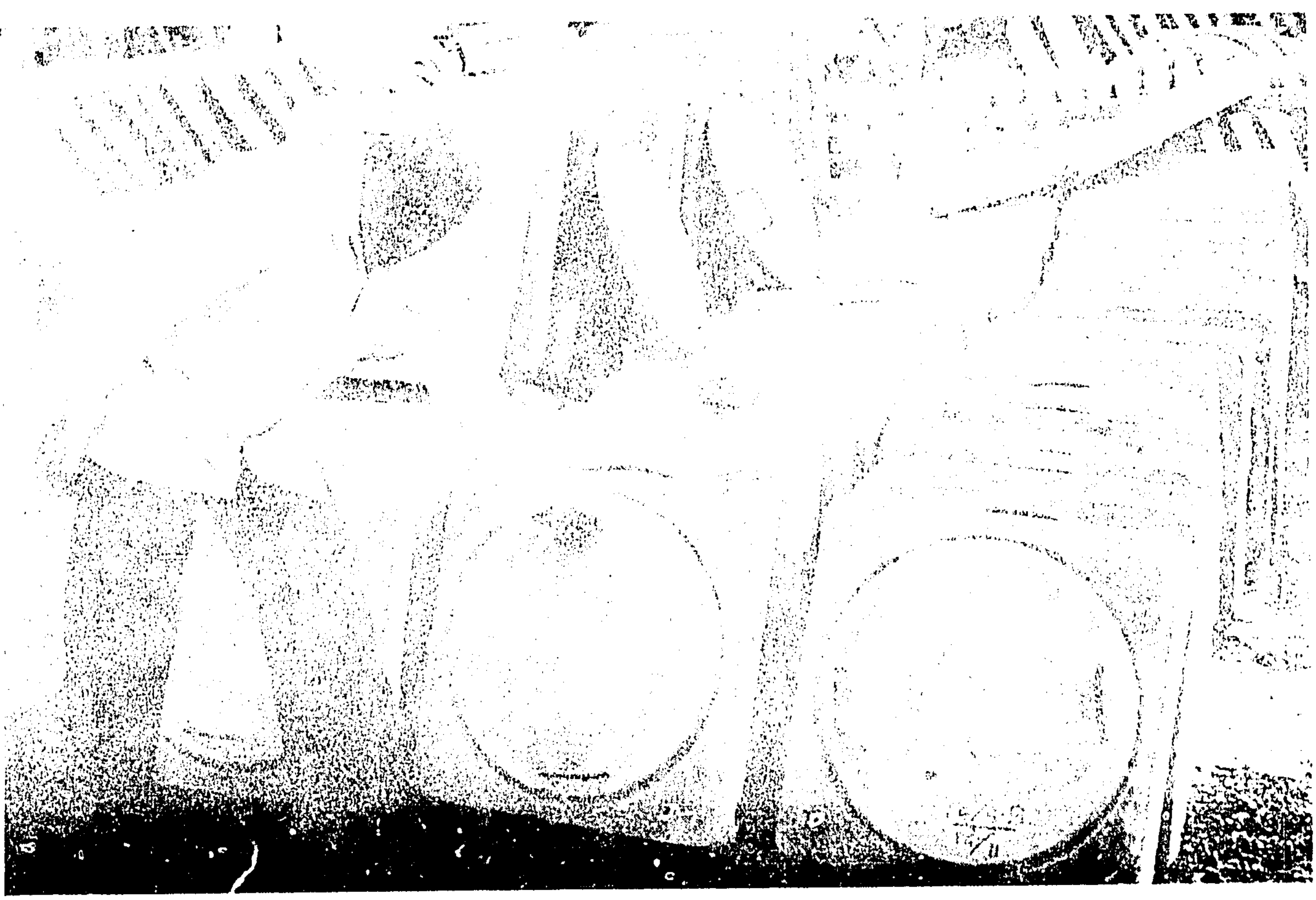


Figure 3.22. Turnout fabricator Hafiz Sadrul Hasan with finished circular concrete turnout panels ready for transport to the sites.

SECTION 4

CIRCULAR TURNOUT PANEL INSTALLATION

Choosing the Proper Lid Size

The proper diameter of the gate will depend upon the water flow rate and the allowable head loss. When water flows through a constriction, it speeds up, then slows down, and part of the flow is bent or redirected to pass through the constriction. These changes cause the energy of the water to be reduced, usually resulting in the depth of flow (or more specifically, elevation of the water surface) downstream being less than the elevation ahead of the constriction. This water surface elevation drop is called head loss, and depends both on the amount of bending of the water flow or shape of the constriction, and upon the amount the flow velocity is increased, then slowed down.

As long as the circular orifices are flowing full, the shape factor will be relatively constant, and only the velocity factor need be considered. Since head loss is a function of the square of the velocity, the relatively slow velocity of flow in the channel above and below the gate can be considered zero (which will result in a slightly high estimate of the true head loss). Thus, head loss through a circular gate can be related to the average velocity of flow through the gate, which is the ratio of the flow rate to the gate cross-sectional area.

Gates flowing full act as submerged circular orifices, and the head loss can be estimated by the equation:

$$H = \left(\frac{1}{C^2}\right)\left(\frac{V^2}{2g}\right) = \frac{1}{C^2 2g}\left(\frac{Q}{A}\right)^2 \qquad (3)$$

where: H = the head loss (m),

C = an orifice discharge coefficient,

V = the flow velocity (m/sec),

A = the cross-sectional area of the gate (m²), and

g = the acceleration of gravity (g = 9.81 m/sec²).

For circular concrete turnouts, the coefficient, C, is about 0.8. Since area is equal to the gate diameter squared times one-fourth of pi (π) (and converting to more convenient units):

$$H = 1291\frac{Q^2}{D^4}, \qquad (4)$$

where: H = head loss (cm),

Q = flow rate (liters per second - lps), and

D = the gate diameter (cm).

Figure 4.1 graphically shows this relationship between gate size, flow rate, and head loss. Notice in Equation 4 that head loss is inversely related to turnout diameter to the fourth power. Because of this, an increase in gate diameter causes a much larger decrease in the head loss. For example, a 10 percent increase in gate diameter results in a 30 percent decrease in head loss.

These calculations assume that the gate is submerged. If the gate flows less than about 80 percent full, the head loss will increase due to the decreased flow cross-sectional area. From full to 80 percent full, head loss does not increase because the effects of the small decrease in cross-sectional area is offset by the lack of flow constriction at the top.

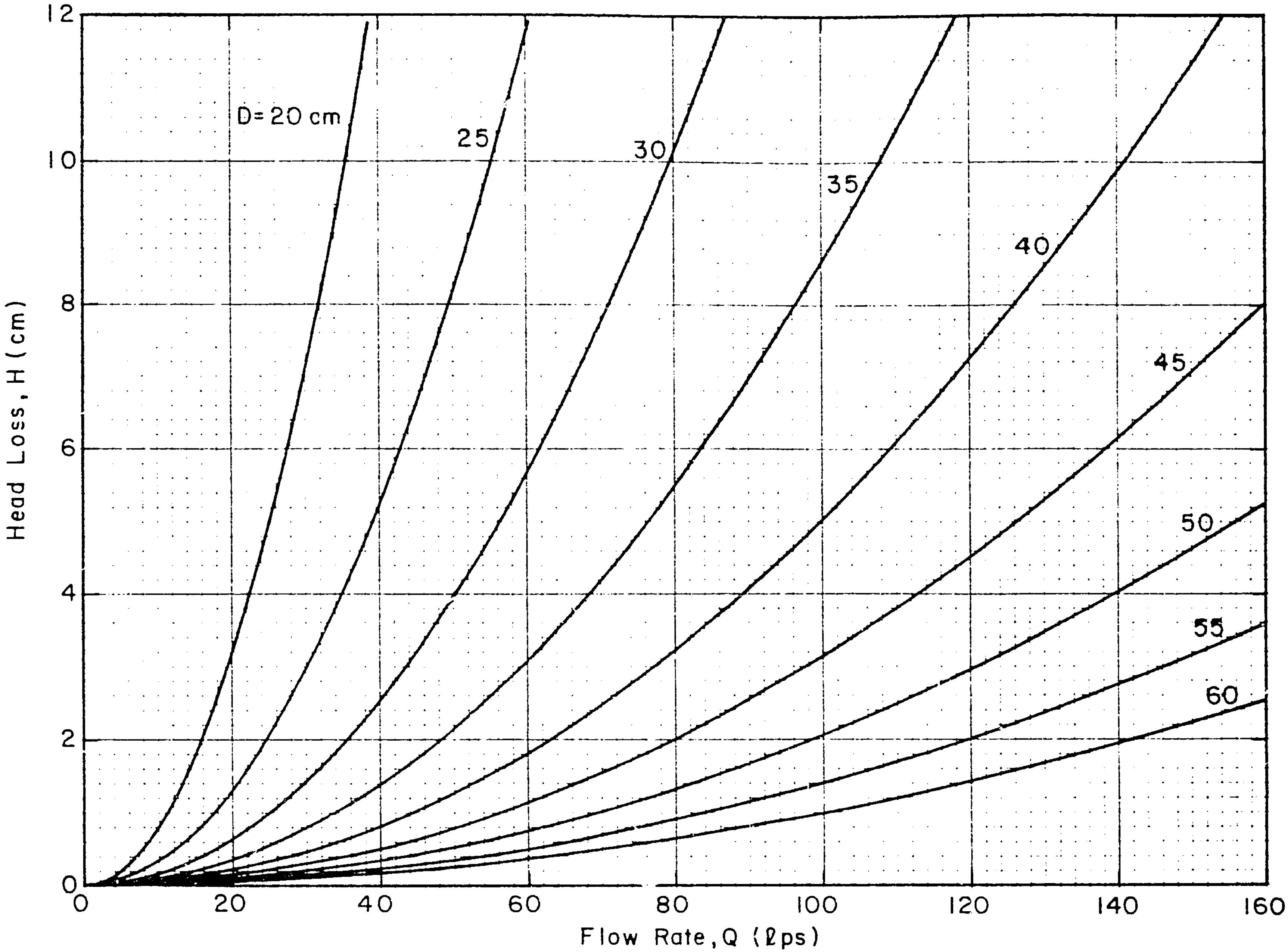


Figure 4.1. Head loss through circular concrete turnouts of various diameters, *D*, flowing full, assuming a submerged orifice coefficient of 0.8.

Determination of allowable head loss depends upon the available channel slope. With small available channel slopes, head loss in structures leaves less energy to move water down the channels and results in a need for larger channels. The cost of the larger channel must be balanced against the cost and more difficult use of larger structures. The *Watercourse Improvement Manual* by Trout and Kemper (1980) explains in detail how to design irrigation channels considering structure head losses.

If channel slopes are greater than 0.001 m/m, structure head loss is not a critical factor and H values of 6 cm or more per structure are acceptable. Care should be taken if structures with high head loss are used, because high head loss will result in turbulence below the turnout. Turbulence can cause erosion and thus require larger, more expensive installations.

As was mentioned, structure head loss is more critical in check structures because water may flow through several checks and the elevation drops would be partially cumulative. For example, in a typical earthen channel built on a slope of 0.0004 m/m, checks spaced 200 m apart which each cause 4 cm of head loss would cumulatively increase the flow depth by 10 cm. Therefore, it may be desirable to design check structures to be larger than turnouts. A disadvantage of using different sizes is that lids cannot be interchanged. In a normal junction with one size of gates, one lid can be used for both the check and turnout, since one gate will always be open and the other closed.

If channel slopes are too steep and cause erosion, the head loss caused by checks can be used to dissipate some of the excess energy. By using Figure 4.1, the size of gate that will create a desired fall in the water level of a given flow can be determined. Installing gates high so that they flow only partially full can also create extra head loss. The flow depth through a circular gate flowing partially full (assuming free or critical flow) can be calculated from circular weir formulas (Bos, 1976) or determined by trial and error. The bottom of the opening should be placed at this depth below the design upstream water surface elevation. The downstream floor of the structure should be at the level of the downstream channel bed. As mentioned, if high head losses are created, erosion protection downstream of the gate must be provided.

Placing the Panels

The turnout and check gates should be installed at an angle of 60° to 65° from the horizontal (or about 2 vertical to 1 horizontal). This backwards slope is sufficient to prevent the lid from slipping out of the panel. The top of the opening should be installed at about the level of the water surface, or slightly higher. Installing the gate higher than this level will result in a partially full gate and high head loss. Installing lower will submerge the lid and make opening against the higher hydrostatic pressure more difficult. The bottom of the lid should not be installed lower than the bottom of the channel to avoid silt deposition on the sealing surface. If new channels are being designed, the structures should be surveyed in. In existing channels, they can be installed according to existing water levels.

Trout, Thomas and W. D. Kemper. 1980. Watercourse Improvement Manual. Water Management Research Project Technical Report #58. Colorado State University, Fort Collins, Colorado.

Bos, M.G., ed. 1976. Discharge Measurement Structures. International Institute for Land Reclamation and Improvement. Pub. #20, P.O. Box 45, Wageningen, Netherlands.

The panel outer dimensions should be sized to fit easily into the installation structure. The top of the installed panel should be 2 to 4 cm below the top of the walls of the installation structure and the channel bank tops. The turnout will thus act as an emergency overflow preventing bank washouts in case the depth of flow into the channel gets too high. Accidental spillage will run into branch channels rather than onto fields.

Turnout Installation Structures

The precast turnout panel must be installed in some type of structure for support, to prevent water from washing under or around it, to provide a channel for water to pass through the bank, and to prevent erosion. In lined ditches, the installation for a turnout might only consist of a lined outlet through the bank (Fig. 4.2). In earthen channels, the installation, such as that shown in Figure 4.3, will need to be more elaborate to provide all of the requirements listed above.

The type of installation structure chosen will depend upon local availability and cost of materials, skilled and unskilled labor availability, and remoteness of the field sites from fabrication centers. If transport costs are low, the efficiency and quality control achievable by precasting structures at central locations might be preferable. If inexpensive building materials such as brick or stone and cheap labor (both skilled and unskilled) are available at or near the field sites, constructing installations at the sites may be desirable. Several types of installation designs will be described here.

Brick masonry installations

In Pakistan, due to the wide availability of inexpensive fired brick from local kilns and the presence of masons in every village, brick masonry structures were used to install the turnout panels in both earthen and lined watercourses. Samples of these structures are shown in Figures 1.1 and 4.3. The standard design for these structures is shown in Figure 4.4.

The installation is a short channel which forms an outlet through the bank with a single brick base and a double brick wall. The panel is attached to the front of the channel section. In smaller watercourses, walls one brick thick are sufficient to support the earth fill. Single brick walls higher than 6 courses (layers) are not recommended. The width and depth of the channel depends upon the flow rate and turnout size. The width should be a little wider than the panel hole diameter. The height should be equal to the design height of the watercourse channel.

The structure length depends upon the erosiveness of the soils and the amount of head loss through the turnout. The head loss causes turbulence and determines the erosive potential of the water. The length should be the minimum required to prevent erosion. In the design shown in Figure 4.4, the side walls are reduced to single brick thickness at the back and stair-stepped down. This reduces costs and increases the flow width, thus reducing flow velocities and erosion. The design also allows a smoother transition to the downstream trapezoidal earthen channels.

With proper compaction of the backfill soil around the structure, leakage under or around the turnout would not be a problem in most soils. However, in Pakistan, compaction was often not sufficient and leakage did occur. The leakage was difficult to detect and stop and sometimes led to bank washouts. This lack of compaction is partially due to the inability to compact the soil around a newly constructed structure because the mortar is not hardened and the walls are weak, and the failure to return to the site to do the compaction later.

Figure 4.2. Turnout panel installed in a lined channel.

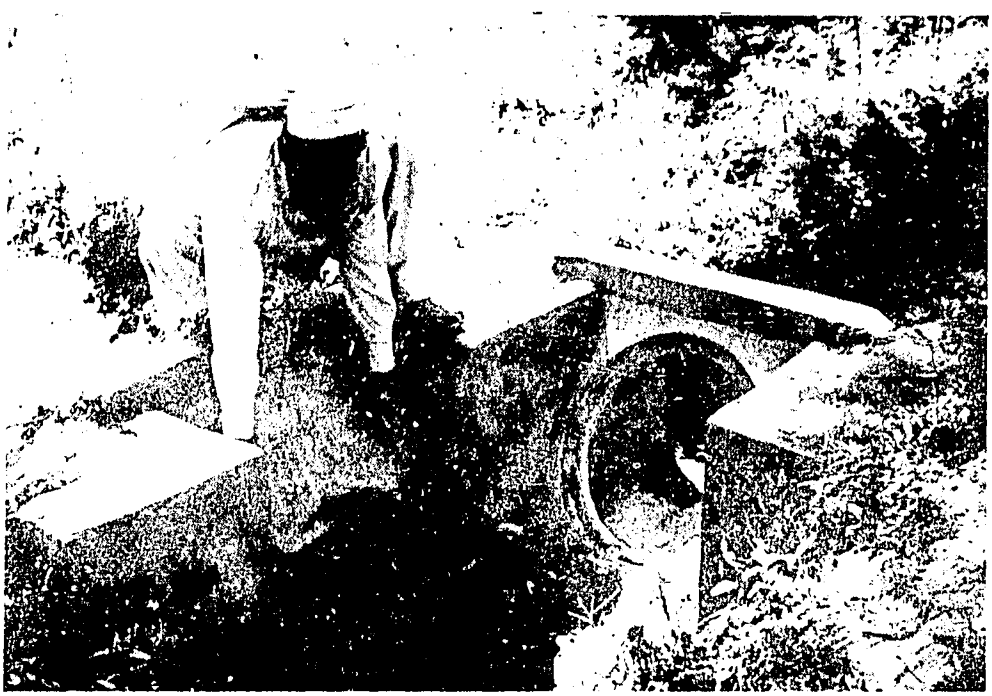


Figure 4.3. Circular concrete check and turnout installed with brick masonry in an earthen channel.

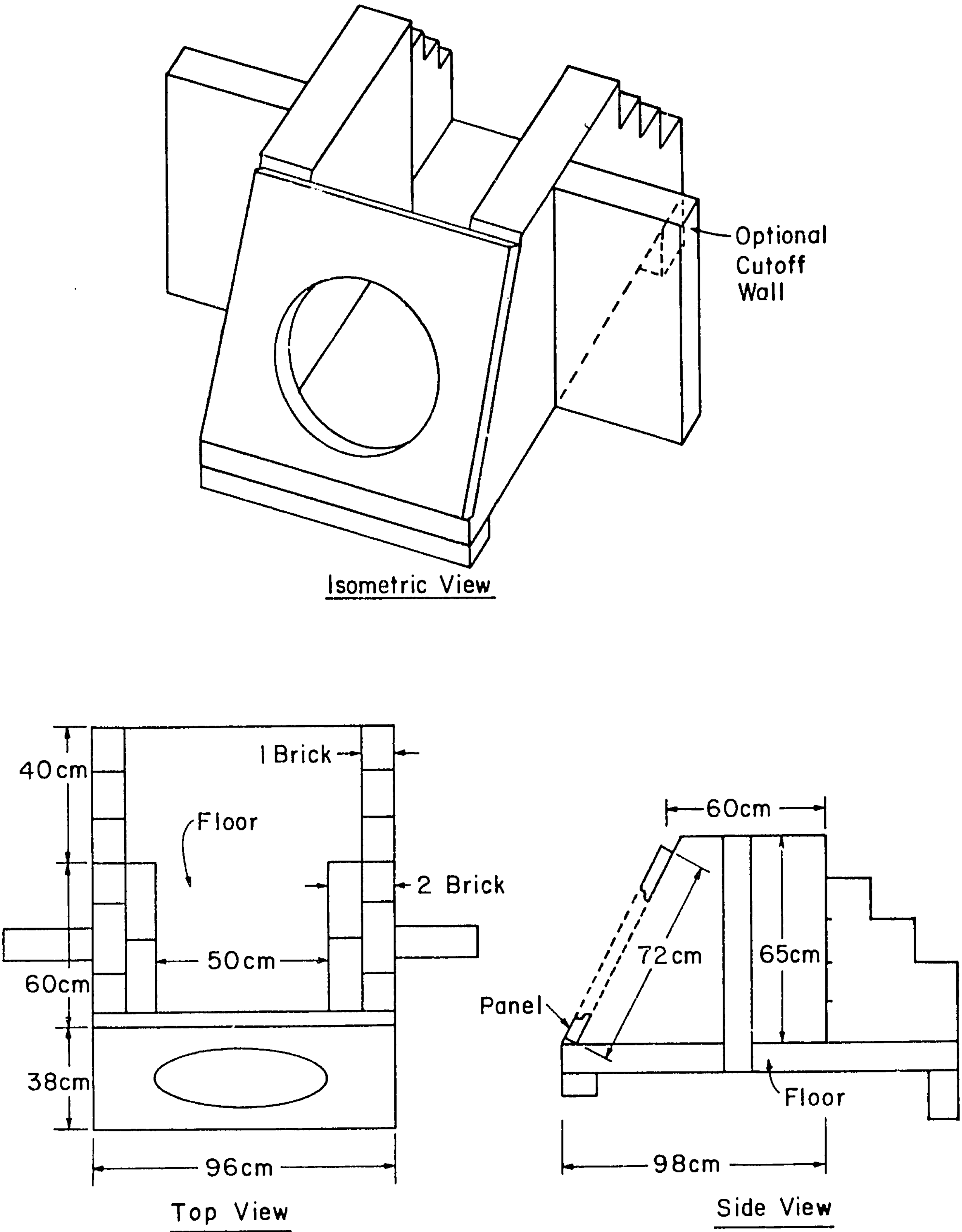


Figure 4.4 Brick masonry installation for panel turnouts. Dimensions shown are for 50 cm diameter turnouts and should be adjusted for other sizes.

If leakage is a problem, cutoff walls must be built around installations in earthen channels. These one brick thick walls extend out about 30 cm from the structures. They can be attached near the center and thus buried in the bank as shown in Figures 1.1 and 4.4, or at the front near the panel as shown in Figure 4.3. Where a check and one or two turnouts are installed together, the front corners of the structures are joined as shown in Figure 4.3 and no cutoff walls are required. Cutoff walls are also not required for installations in lined channels where the lining prevents leakage.

The installations are made by excavating the site and compacting the earth bed, laying the floor, then supporting the turnout panel at the proper location, orientation, and elevation, and constructing the masonry structure around it, as is being done in Figure 4.5.

Normal procedures for constructing good quality brick masonry should be followed. A 1:3 cement:sand ratio should be used. The sand and water should be clean. The bricks should be of good quality. In hot, dry climates, the bricks should be soaked before construction and the structure kept wet for two or three days after completion for curing. This can be accomplished by spreading a layer of loose soil or mulch on the structure and wetting it down.

If bricks are not easily available or are expensive, the structures can be made from soil-cement blocks, stone masonry, precast concrete blocks, or poured-in-place concrete. The last of these alternatives can provide the most durable installation if constructed properly. Concrete mixes of 1:2:4 proportions are sufficient for such installations. Regardless of the materials, the installation structure should follow the basic design given in Figure 4.4.

Precast concrete slab installations

Precasting installation structures saves time in the field and results in more uniform quality. Figures 4.6 through 4.9 show some precast installations for earthen channels tested in Pakistan. Generally the installation is cast in two or more pieces for easier transport. The parts should be easy to assemble in the field.

Figure 4.5. Brick masonry installations being constructed.

Figure 4.6. Precast concrete slab installation.

Figure 4.7. Concrete pipe installation with front panel.

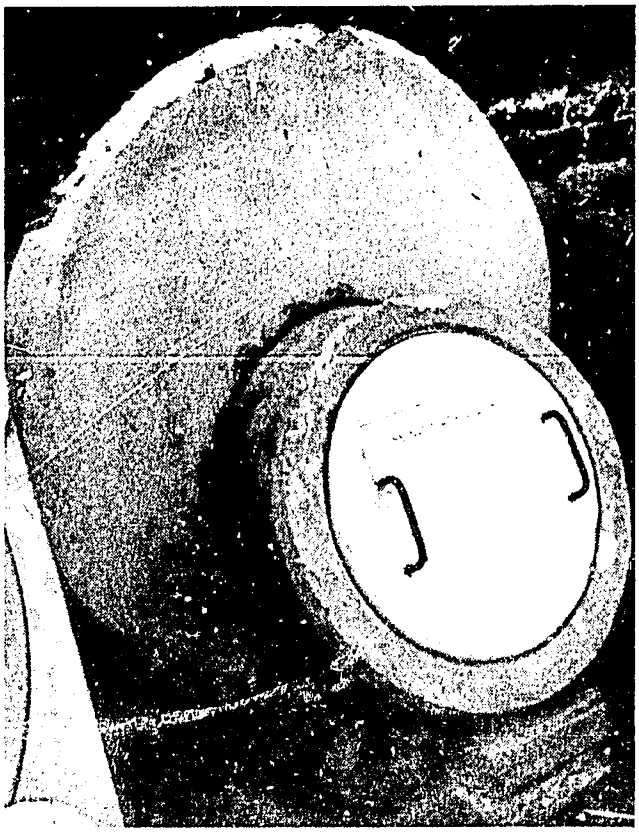


Figure 4.8. Concrete pipe installation with collar.

Figure 4.9. Half pipe installation with front panel and trapezoidal gate.

Figure 4.6 shows a concrete slab installation composed of a bottom and two sides which support the front panel. Suggested dimensions of the components to be used with a 50 cm diameter turnout are given in Figure 4.10. Smaller structures can be used with smaller turnouts. The side walls are slanted outward to merge more easily with trapezoidal channels. The walls are angled outward toward the back to increase the cross-sectional area and reduce flow velocities and erosion. The front panel is enlarged to extend into the bed and banks of the earthen channel and serve as cutoff walls. Because soil can be compacted around the structure immediately, the problem of leakage around the structure can be reduced. For two or three adjoining structures, one side of the front panel of the second and third structure should be formed as shown by the dashed lines in Figure 4.10, so that it can lay up against the adjoining panel.

Grooves are cast onto the back of the panel and top of the floor section to hold the walls in place. These grooves can be made without weakening the slabs by laying a board which is a little wider than the thickness of the walls in the proper position on the surface of the freshly poured slab, and trowelling concrete up against the edges of the board. This will result in a groove such as that shown in Figure 4.10 cast onto rather than into the slab. No additional fastening other than the grooves should be required.

The slabs should be cast as thin as possible in order to reduce weight and handling difficulties. Three to four centimeters should provide sufficient strength if the concrete work is of good quality. The slabs must be reinforced to prevent damage while in transit.

Concrete pipe installations

Figures 4.7 and 4.8 show two precast installations made from reinforced concrete pipe. These structures are most applicable for turnouts through earthen banks or to combine a check structure with a culvert or channel overpass. The pipe replaces the outlet channel that passes through the banks. An advantage of the structure is that, because it is buried in the bank, it does not interfere with human or animal movement along the banks and can be adapted to channels where mechanical cleaning is used. A disadvantage is that, to reduce weight and cost, the pipe's cross-section is generally small and exiting water may flow fast enough to cause erosion problems. It is also bulkier and more difficult to transport to remote sites.

Two types of pipe installations are shown. In Figure 4.7, the turnout frame is cast into a panel that is then attached to the front of a pipe. The panel is enlarged to serve as a cutoff wall and cast in a round shape so that it can be rolled to the site. The end of the pipe is cast with a 30° angle at one end so that the panel, when attached to it will sit at a 60° angle along the channel bank. This angle is formed by placing an elliptical ring with the long outside diameter (axis) 15 percent longer than the short axis, (which is equal to the outside diameter of the pipe) inside the casting cylinder. If the pipe is cast in a 2.4 m (8 ft) spin mold, two 1.2 m pipes, each with one angled end, can be made if the elliptical ring is inserted in the center of the mold.

The diameter of the pipe must be as large as, or larger than, the diameter of the turnout. Larger pipes will cost more and be more difficult to transport, but will cause less erosion. The length must be sufficient to pass through the channel bank.

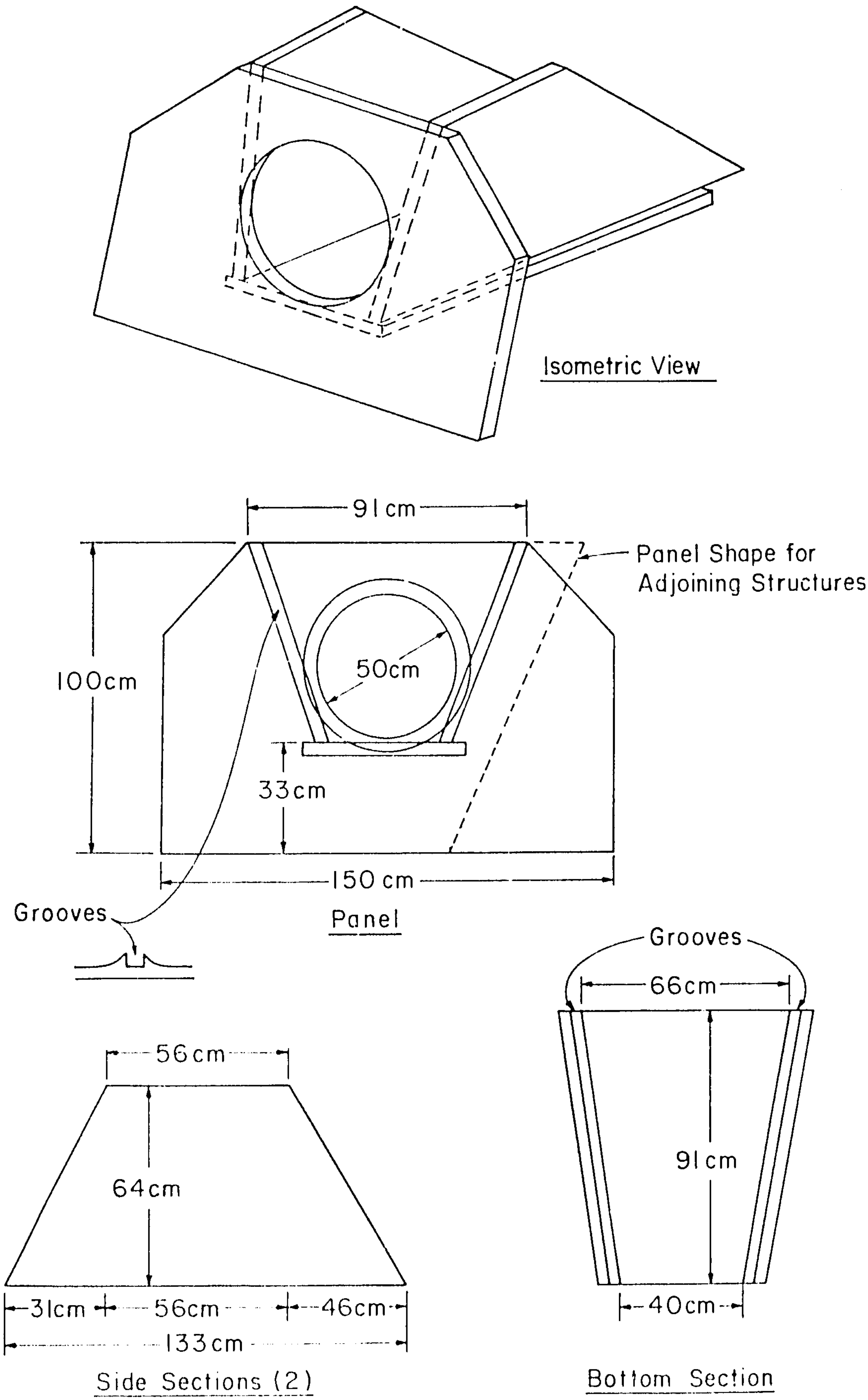


Figure 4.10 Precast concrete slab installation for panel turnouts. Dimensions shown are for a 50 cm diameter turnout.

In the concrete pipe installation shown in Figure 4.8, the turnout frame is cast or inserted directly into the end of the pipe, while a collar through which the pipe is inserted serves as the cutoff wall. The pipe is made with a 30° bend near the front. This bend is made by casting the pipe in two pieces, each with a 15° angled end. When one of these two pipe pieces is rotated 180° with respect to the other, the ends match creating a 30° bend in the pipe. They can then be attached with mortar and steel mesh reinforcement. The angled ends are formed using the same type of elliptical insert in the mold as described earlier, except the long axis is only 3½ percent longer than the short axis. The casting process is illustrated in Figure 4.11.

An additional installation option using reinforced concrete pipe is to use a half pipe as shown in Figure 4.9. This installation is especially useful if the turnouts flow only half full or if rectangular or trapezoidal turnouts are used. The half pipe is manufactured by placing two straight sheet metal insert strips longitudinally in the mold cylinder opposite each other.

The installation structure used in a given location will depend upon available resources and conditions. Many types and designs of structures in addition to those mentioned are possible. The installations described and pictured in this section can most effectively be used as a source of ideas from which structures adapted to local conditions and resources can be developed.

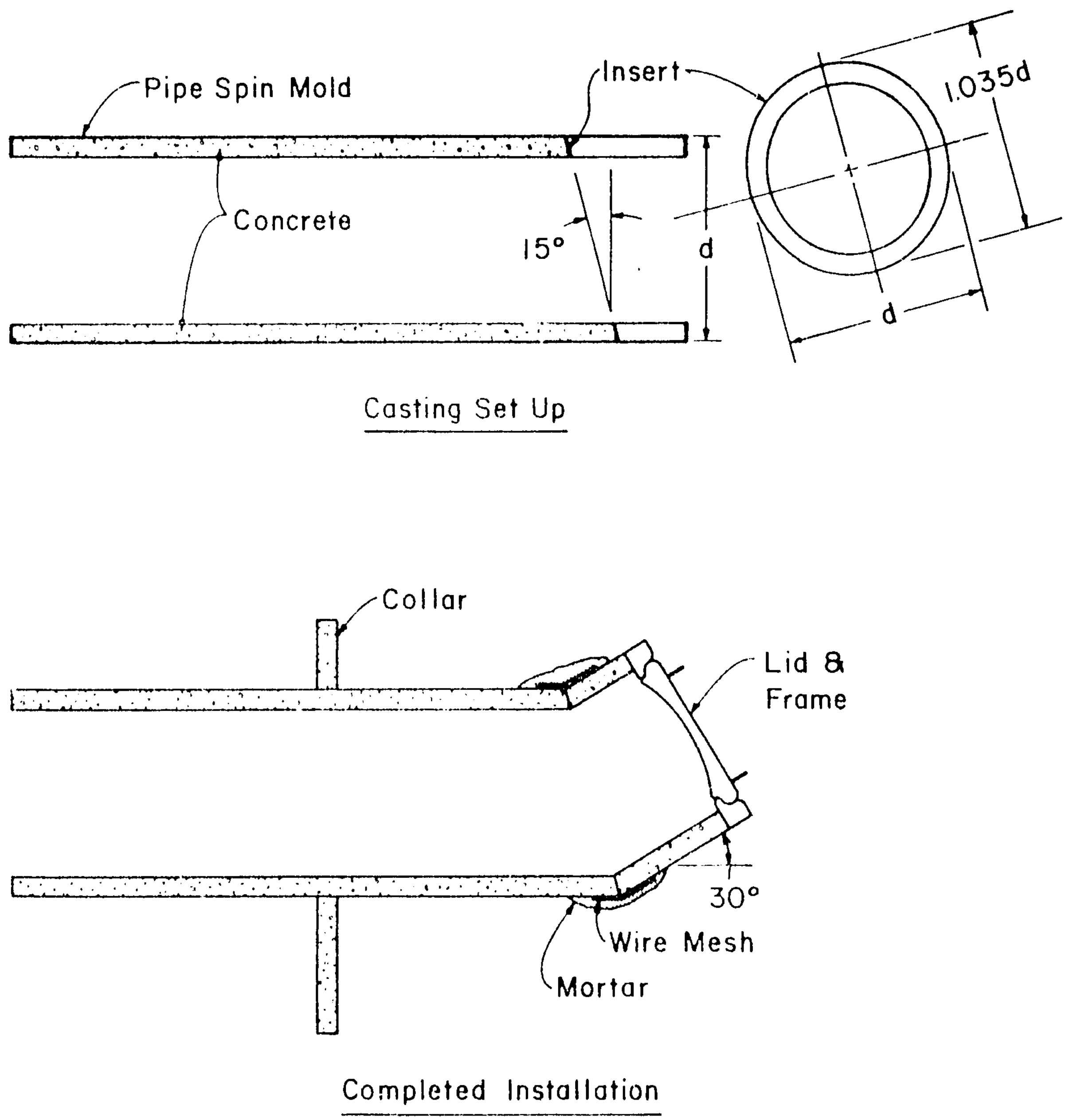


Figure 4.11. Illustration of method to make 30° bend in a concrete pipe for a pipe installation.

SECTION 5

ALTERNATIVES TO THE BASIC CIRCULAR CONCRETE TURNOUT DESIGN

During the development of the circular concrete turnout structures, several alternative lid and frame designs were built and tested. Although these were determined not to be best for Pakistan conditions, they might be desirable under other conditions, or give ideas for improved adaptations for other environments. They are, therefore, briefly described here. All variations are based on the panel and lid concept and use concrete as the basic building material. The variations fall into two categories: those which use materials other than concrete for the lid or sealing surface and variations from the circular shape.

Lid or Sealing Surface Materials Other than Concrete

Large concrete lids are heavy. This limits the practical size of circular concrete turnouts, makes use of the gates more difficult, and increases chipping and breakage when the lid inadvertently strikes the panel or installation structure. The use of lower weight lids is thus advantageous.

Because the frame is rigid, the circular lid needs little structural rigidity. The hydrostatic pressure of the water holds the lid firmly in the round frame. In fact, flexible lids can be easier to open because one side can be bent forward to let water leak through and relieve the water pressure. Therefore, simple sheet metal, plastic, or fiberglass disks with handles can be used in concrete panels with the square sealing surface (Figure 5.1). The surfaces of both the lid and concrete frame must be very smooth to prevent leakage. Such leak-free seals were not attained in Pakistan.

A similar alternative would be to form a rigid fiberglass lid to fit the curved sealing surface frame. The cast concrete sealing surface could be used as the mold for the fiberglass to insure a good fit. One design for such a lid is shown in Figure 5.2. Any deflection in the lid would actually seat the lid more tightly against the panel sealing surface.

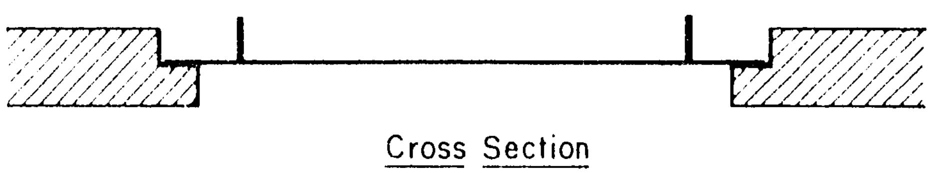


Figure 5.1. Sheet metal, plastic, or fiberglass disk lid in a circular concrete panel.

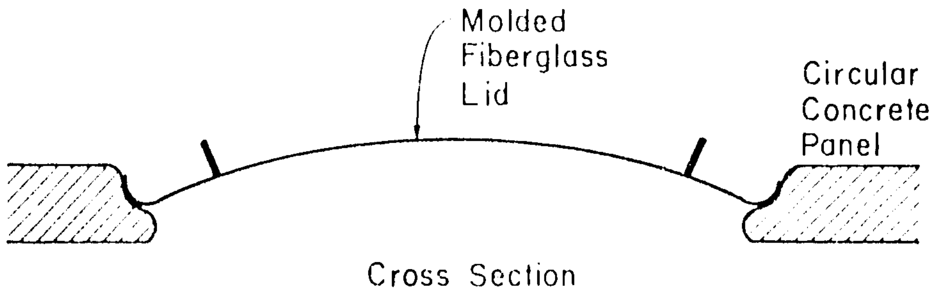


Figure 5.2. Molded fiberglass lid for the circular concrete panel.

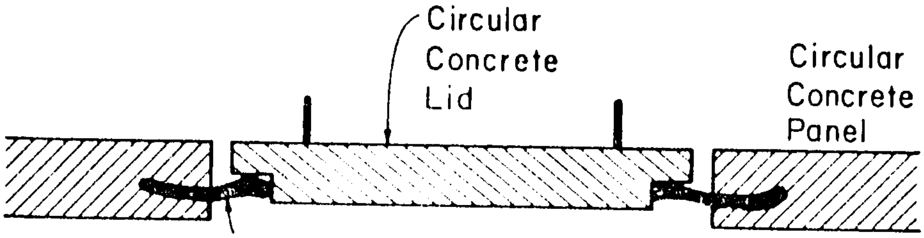


Figure 5.3. Circular turnout with rubber tire sidewall sealing surface.

Early in the development of circular concrete turnouts, leakage was a problem. Therefore, flexible inserts such as rubber gaskets around the sealing surface were tested. These took the form of sponge rubber glued to the lid, hard rubber "O rings" cast into the lid, and the sidewall of a used rubber tire cast into the panel. The sponge rubber gaskets proved leak-proof as long as they were intact, but deteriorated quickly or were torn loose. The hard rubber seals were not flexible enough to deform to irregular shapes and thus leaked unless the concrete panel surface was smooth and uniform. The rubber gaskets, especially the rubber tire sidewall design shown in Figure 5.3, cushioned the impact of the lid on the panel and reduced chipping. Rubber gaskets could also be used with the metal or fiberglass lids described above.

Other Turnout Lid Shapes

The primary disadvantage of the circular turnout is that the lid must be opened from in front against the hydrostatic pressure of the water. Lids that can be removed from above or slid on runners without lifting the lid off of the frame could thus be easier to remove. Figures 5.4 to 5.7 show several such gates.

Figure 5.4 shows a trapezoidal-shaped concrete turnout gate. The gate can be removed from above, and is thus easier to remove. However, it is harder to close while water is flowing because the lid tends to be pushed through the opening or wedged crooked against the frame. Also, silt which deposits on the seat is not as easy to remove as from the round opening; and if not removed, causes incomplete closure and significant leakage. Making the lids in a semicircular shape so they can be rotated can solve this silt problem. The trapezoidal lid is heavier than a circular lid for a given flow area because it must extend above the water surface to provide a freeboard. Semicircular lids are even heavier due to the wider top width required to achieve the same flow area. Thus the trapezoidal and semicircular shapes are better suited to smaller flows.

The trapezoidal lid, shown in more detail in Figure 5.8, is cast in a precision mold machined in a milling machine. The molds are thus more expensive than circular molds. The frame is then cast around the precast lid - as the circular lids were cast in their panel - to insure a good fit. However, the sealing surfaces cannot be ground together, and thus tend to be rougher.

The rectangular sliding turnout shown in Figure 5.5 is very easy to use. The lid never has to be lifted or removed from the frame. Thus large size lids can be used if low head loss is required or if the flow depths are large. The lid can be pinned or otherwise fastened at any elevation allowing flows to be divided or flow depths regulated.

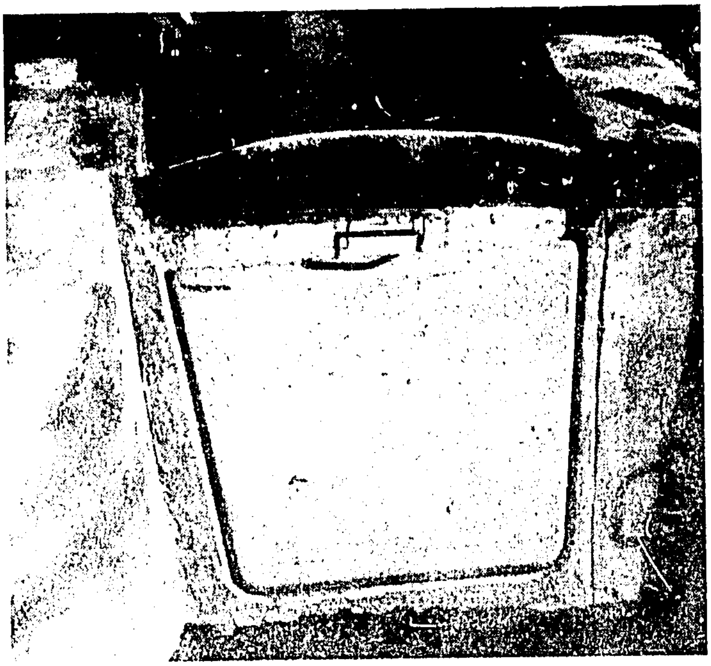


Figure 5.4. Trapezoidal concrete turnout.

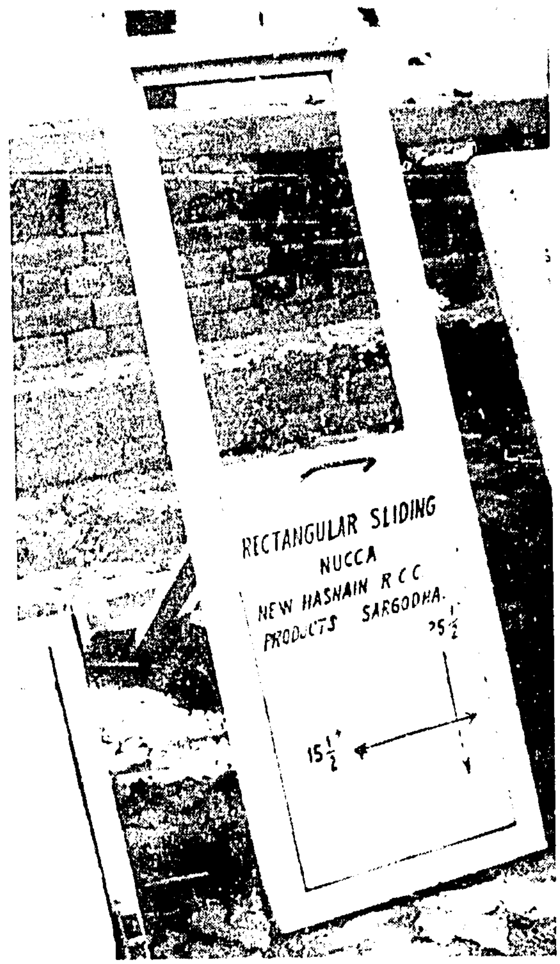


Figure 5.5. Rectangular sliding turnout.

Figure 5.6. Circular rotating turnout with half-circle cutout.

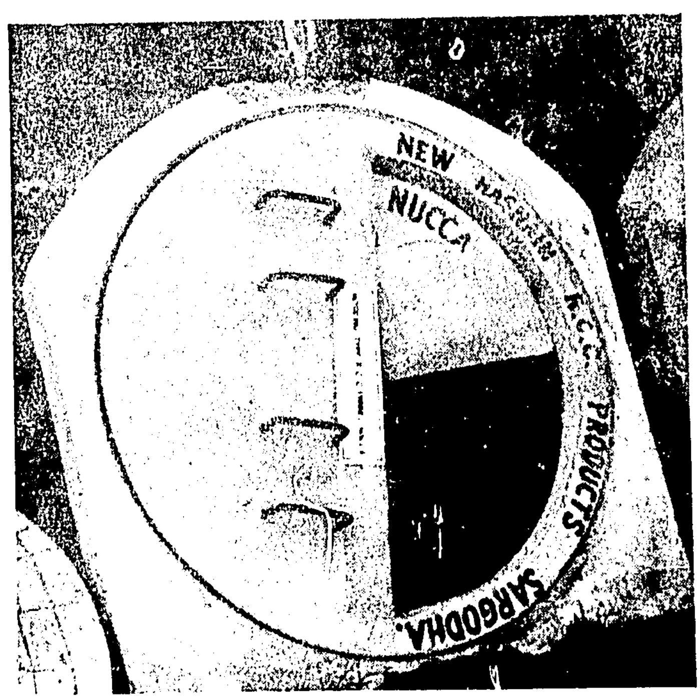


Figure 5.7. Large circular rotating turnout with half-circle cutout.

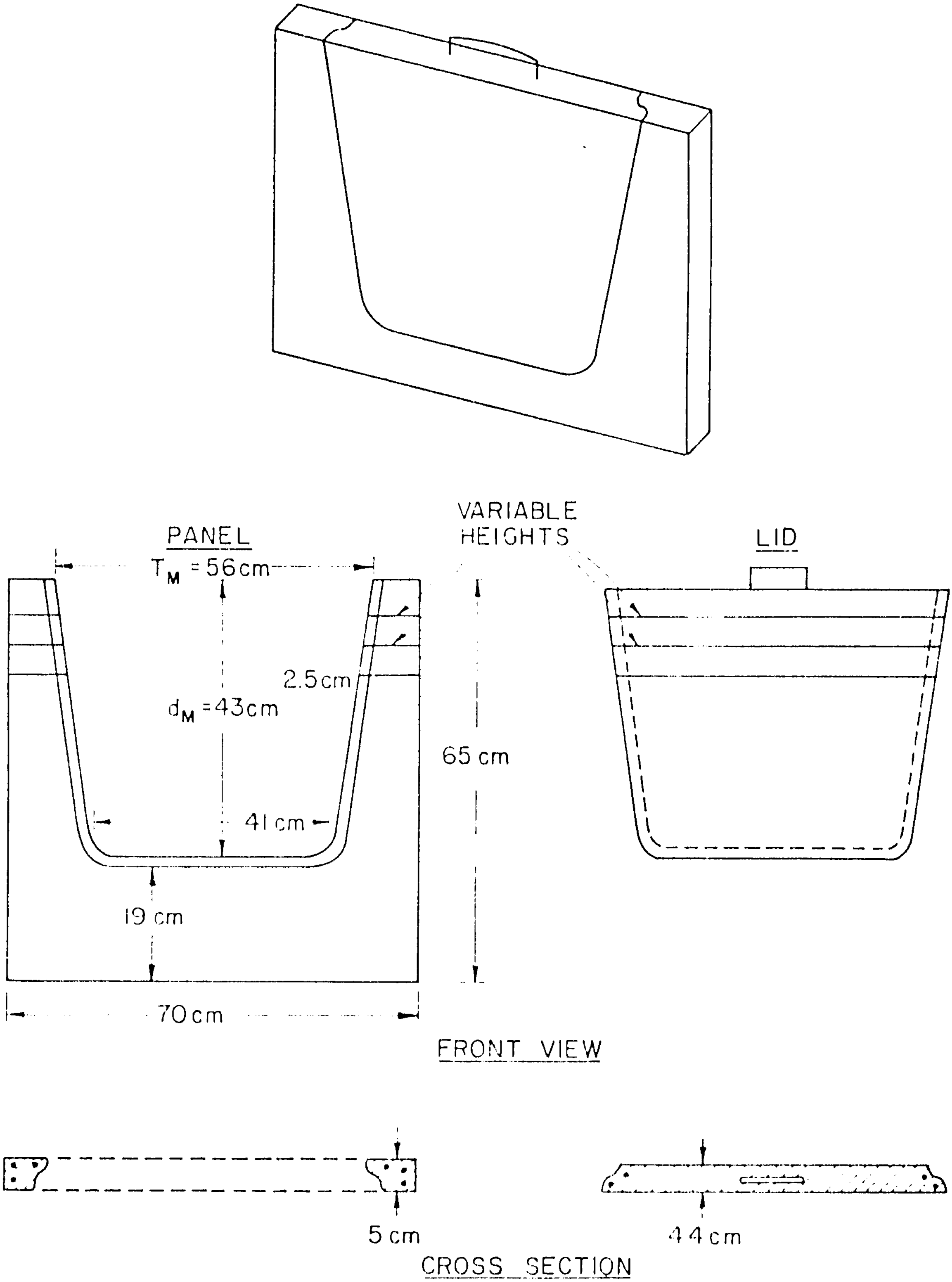


Figure 5.8. Trapezoidal concrete panel turnout.

However, no rectangular sliding turnouts were made that did not leak. If the lid or panel is slightly warped or has any small protrusions, a crack is left open and leakage is large. The sliding also quickly wears away rubber gaskets installed to stop leakage.

Figures 5.6 and 5.7 show circular rotating turnouts, composed of a circular concrete lid with a semicircular portion cut out. The lid never needs to be removed from the panel, but only rotated so that the open half rotates from the top (closed) to the bottom (open). The lid allows easy adjustment of flow rates. The structure, however, can only be used for relatively small flows, since less than half of the circular area is open, and must be used in channels where the flows are relatively shallow (less than half as deep as the circle diameter). However, since the lid doesn't have to be removed, larger lids can be used. Figure 5.7 shows a 75 cm diameter lid which is rotated by inserting a rod through the handles and turning. Since the circular rotating lid is never removed, chipping and breakage is not a problem; although eventual wearing and loosening of the sealing surface could be a problem.

The rotating turnouts are cast in the same way as the regular circular turnouts, except a semicircular insert is cast into the lid and later removed. Lips extending over the edges of the lid (Figure 5.6) can be cast into the panel to insure that the lid is never removed or stolen.

These widely varied designs, all based on one basic structure, should give an idea of the variety of turnouts that are possible. Because they were not best for Pakistan conditions doesn't mean they can't work in different environments. They instead should indicate the importance of understanding local needs and conditions, designing a turnout to satisfy the needs, and then patiently following through the development and fabrication process until a good, durable, practical structure is created.

APPENDIX I

CONCRETE FOR SMALL JOBS

concrete information

PORTLAND CEMENT pca ASSOCIATION

Concrete for Small Jobs

Concrete is a widely used building material around the farm and home. Foundations, walls, sidewalks, patios, steps, floors, and driveways are built by homeowners everywhere. Concrete has several desirable properties that make it a versatile and popular building material. Freshly mixed concrete can be formed into practically any shape. Hardened concrete is strong and durable.

The layman often confuses the words "cement" and "concrete."

Cement is the fine powder sold by building materials dealers in bags. It should be called by its more exact name, "portland cement," to differentiate it from other kinds of cements used for other purposes, such as, for example, masonry cement.

Concrete is the mixture of two components, paste and aggregates. Paste is composed of portland cement, water, and air. Aggregates are inert minerals such as sand, gravel, and crushed stone.

During mixing, the cement and water form a paste that coats the surface of every piece of aggregate. Usually within two to three hours after mixing, a chemical reaction starts between the cement and the water. As this chemical reaction progresses, the cement paste hardens gradually and the concrete is said to set. Finally, the cement-water paste will harden much like glue and bind the aggregates together to form the solid mass that is concrete.

Although ready mixed concrete is widely used for large construction jobs, it is not always practical to use ready mixed concrete on small jobs. In some cases, the amount of concrete you require may be less than 1 cu.yd., which is less than most ready mix producers will supply. And in some areas there is no ready mix plant.

If you are faced with one of these circumstances, making your own concrete may be the only practical solution. This is hard work but it has the advantage of low cost, and the amount of concrete mixed can be adjusted to suit your own work pace.

Quality concrete costs no more to make than poor concrete, but is far more economical in the long run because of its greater durability. The rules for making good concrete are simple:

1. Use proper ingredients.
2. Proportion the ingredients correctly.
3. Measure the ingredients accurately.
4. Mix the ingredients thoroughly.

CHOOSING THE INGREDIENTS

Portland cement is not a brand of cement but a type. Most portland cement is grey in color. However, white portland cement is manufactured from special raw materials that produce a pure white color. It can be used instead of the normal grey portland cement, but it is higher in price, which may restrict its use to decorative work and other special jobs.

You can buy portland cement in bags at your local building materials dealer. In the United States, a bag weighs 94 lb. and holds 1 cu.ft.; in Canada, a bag weighs 80 lb. and holds about ⅞ cu.ft.

Cement in bags should be stored in a dry location, preferably on raised wooden platforms. Sometimes when bags have been stored for a long time, the cement in the lower part of a pile develops warehouse pack, that is, the cement appears to be hardened around the edges of th. bags. You can usually correct this by rolling the bag on the floor. To avoid warehouse pack, bags should not be stacked more than seven high.

Cement suitable for use in concrete should be free-flowing. The presence of lumps that cannot be pulverized readily between your thumb and finger indicates that the cement has absorbed moisture. Such cement should never be used for important work, but when the lumps have been screened out through an ordinary house screen, it can be used for certain minor jobs such as setting fence posts.

Water for making concrete can be almost any natural water that is drinkable and has no pronounced taste or odor. Although some waters that are not suitable for drinking will make satisfactory concrete, to be on the safe side, use only water fit to drink.

Air is also an important ingredient for making good concrete. In the late 1930's, it was discovered that air in the form of microscopic bubbles evenly dispersed throughout the concrete improved its durability and virtually eliminated scaling due to freeze-thaw and de-icer salt action. Concrete containing such air bubbles is called air-entrained concrete.

Hardened concrete usually contains some water. When this water freezes, it expands, causing pressure that can rupture (scale) the concrete surface. The tiny air bubbles act as reservoirs or relief valves for the expanding water, thus relieving pressure and preventing damage to the concrete.

Air entrainment is most important for concrete exposed to alternate cycles of freezing and thawing or use of de-icers. In cold climates, and even in mild climates that have several cycles of freezing and thawing each year, it should be used for all exterior concrete work, including driveways, sidewalks, patios, and steps.

Air entrainment also has other advantages. For example, the tiny air bubbles act like ball bearings in the mix, increasing its workability, with the result that less mixing water is required.

To create the tiny air bubbles in air-entrained concrete, chemicals specially made for this purpose, called air-entraining agents, are added to the mixing water. Building materials suppliers sometimes carry air-entraining agents. Ready mix plants stock them for their own use and would probably sell you a small quantity. The amount to be added to the mix depends on the brand of air-entraining agent. This information can be obtained from the building materials supplier or the ready mix producer.

There is another method of obtaining air-entrained concrete. To save you the trouble of buying and measuring an air-entraining agent (and eliminating a possible error in dosage), many cement manufacturers market portland cements that contain an interground air-entraining agent. These cements are identified on the bag as "air-entraining" and are available from the same suppliers that sell regular portland cements.

Aggregates are minerals such as sand, gravel, and crushed stone that make up 60 to 80 percent of the volume of concrete. They act as an inert filler material to reduce the amount of cement required in concrete. Without aggregates, concrete would be very expensive. Furthermore, without aggregates, concrete would shrink a great deal upon drying and this would lead to excessive cracking. Aggregates restrain the shrinkage that occurs when concrete hardens.

Aggregates are divided into two sizes, fine and coarse. Fine aggregate is always sand, and coarse aggregate is usually gravel or crushed stone.

Natural sand is the most commonly used fine aggregate; however, manufactured sand, made by crushing gravel or stone, is also available in some areas. Sand should have particles ranging in size from ¼ in. down to dust-size particles small enough to pass through a No. 100 mesh sieve (10,000 openings to the square inch). *Mortar sand should not be used for making concrete since it contains only small particles.*

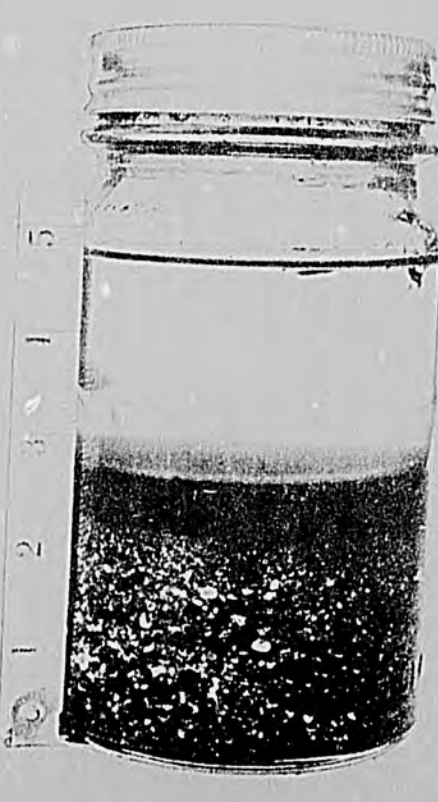
Gravel or crushed stone are the most commonly used coarse aggregates. They should consist of particles that are sound, hard, and durable, not soft or flaky, with a minimum of long, sliver-like pieces. Particles should range in size from ¼ in. up to the maximum size used for the job. The common maximum sizes are ⅜, ½, ¾, 1, or 1½ in. Generally, the most economical mix is obtained by using the largest-size coarse aggregate that is practical or available. Coarse aggregate up to 1½ in. in size, for example, may be used in a thick foundation wall or heavy footing. In walls, the largest pieces should never be more than one-fifth the thickness of the finished wall section. For slabs, the maximum size should not exceed one-third the thickness of the slab. If concrete is to be placed around reinforcing bars or pipes, the maximum size of the aggregate should not be more than three-fourths of the clear space between the bars or pipes, or between the form and the pipe or bar closest to it.

All sizes of aggregates may not be available locally, but within the above limitations, try to use the largest-size aggregate readily available.

Both fine and coarse aggregates for making concrete must be clean and free of excessive dirt, clay, silt, coal, or other organic matter such as leaves, roots, etc. These foreign materials will prevent the cement from properly binding the aggregate particles together, resulting in porous concrete with low strength and durability.

If you suspect that the sand contains too much extremely fine material, such as clay and silt, check its suitability for use in making concrete by the so-called silt test (Fig. 1). Fill an ordinary quart canning jar or milk bottle to

Fig. 1. Silt test being made in a quart canning jar.



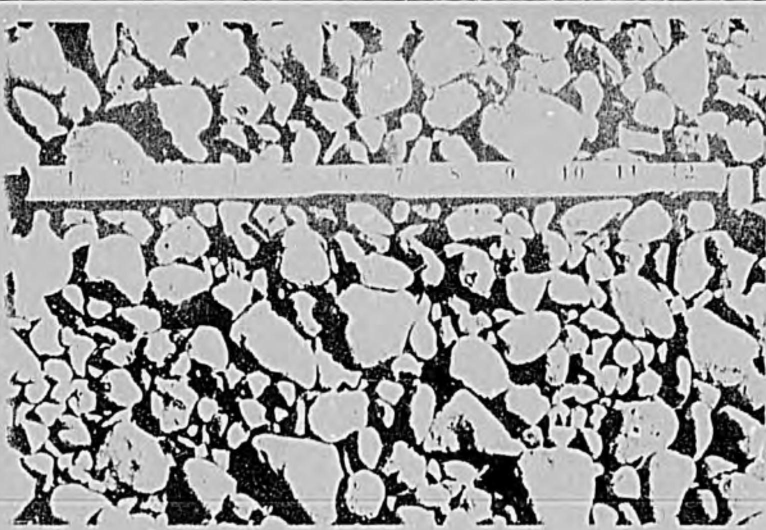


Fig. 2. Well-graded aggregates have particles of various sizes. Shown here is 1½-in. maximum-size coarse aggregate. Pieces vary in size from ¼ to 1½ in.

a depth of 2 in. with a representative sample of the sand in question. The sample should be taken from at least five different locations in the sand pile and thoroughly mixed together. Add clean water to the sand in the jar or bottle until it is about three-quarters full. Shake the container vigorously for about a minute. Use the last few shakes to level off the sand. Allow the container to stand for an hour. Any clay and silt present will settle out in a layer above the sand. If this layer is more than ⅛ in. thick, the sand is not satisfactory unless the clay and silt are removed by washing.

Good fine and coarse concrete aggregates have a full range of sizes from the smallest to the largest, but no excess amount of any one size. The big particles fill out the bulk of a concrete mix and the smaller ones fill in the spaces between the larger ones. Aggregates with an even distribution of particle sizes are said to be well graded (Fig. 2). Such aggregates produce the most economical and workable concrete. Mixtures of fine and coarse aggregates taken directly from gravel banks or stone crushers usually contain an excess of sand in proportion to coarse material. Before using this material in concrete, it should be screened and recombined into properly graded fine and coarse aggregates.

Buy fine and coarse aggregates separately from a reputable building materials supplier. If there is a ready mix producer in your area, it is preferable to purchase aggregates from him. He will make sure that the aggregates you buy have the correct sizes and are suitable for making concrete.

Store aggregates on a clean, hard surface, if possible, and not directly on the ground. Apart from wastage of material, ground storage may cause contamination with mud and dirt. It is good practice to cover aggregate piles to prevent them from becoming wet in case of rain. Do not use the bottom layer of an uncovered aggregate pile, as this part is usually saturated with water and may contain an accumulation of dirt washed through from higher layers.

PROPORTIONING THE INGREDIENTS

In concrete, the cement and water form a paste that surrounds every piece of aggregate. Within a few hours, the concrete starts to harden due to hydration, a chemical reaction between cement and water. As hydration occurs, the paste binds the aggregate together into a strong, durable, solid mass.

The quality of the concrete is directly related to the quality of the cement paste. The quality of the paste, in turn, is directly related to the amount of water mixed with the cement. If too much mixing water is used, the paste will be thin and diluted, making the concrete weak and porous. As the amount of water is reduced, the strength of the paste increases, making the concrete stronger and more durable.

To find the correct amount of mixing water, use the proportions given in Tables 1 or 2 as a starting point. These proportions may not always give a workable mix with your aggregates. However, simple adjustments in the mix can be made, as will be explained in Adjusting the Trial Batch on page 7.

The values in Table 1 should be used if you are measuring your materials by weight. Measuring by weight rather than by volume is recommended for reasons that will be explained in Measuring the Ingredients, page 4.

The proportions in Table 1 are based on use of coarse aggregates consisting of gravel. Gravels are more or less smooth and rounded, while crushed stone aggregates are rougher and more angular. Angular particles produce mixtures that are a little more difficult to work than mixtures with rounded particles, hence a little less crushed material must be used in each cubic foot of concrete to obtain the same workability. Accordingly, when using crushed stone, reduce the value for coarse aggregate in Table 1 by 3 lb. and increase the value for sand by 3 lb.

The weights of material given in Table 1 will make a 1-cu.ft. batch. This is about the right amount for hand mixing. For machine mixing, multiply the values in Table 1 by the capacity of the mixer. For example, if your mixer capacity is 3 cu.ft. and you are making air-entrained concrete with ¾-in. maximum-size gravel aggregate, you would weigh out 25 × 3 = 75 lb. of air-entraining cement, 42 × 3 = 126 lb. of sand, 65 × 3 = 195 lb. of gravel, and 10 × 3 = 30 lb. of water. If you are using crushed stone of the same size, weigh out 3 lb. per cubic foot more sand, or 45 × 3 = 135 lb. of sand instead of 126, and 3 lb. per cubic foot less coarse aggregate, or 62 × 3 = 186 lb. of crushed stone instead of 195 lb. of gravel.

The proportions given in Table 2 are by volume or parts and can be measured in pails, cans, or any other sturdy container. An ordinary galvanized steel water pail makes a convenient batching container.

Estimating quantities needed. Before getting down to the job of measuring and mixing, you will need to know just how much cement, sand, and coarse aggregate to buy for your project. To do this you will first have to estimate the amount of concrete your project will require. Use the following simple formula, which works for any square or other rectangular-shaped area.

$$\frac{\text{Width (ft.)} \times \text{Length (ft.)} \times \text{Thickness (in.)}}{12} = \text{Cubic feet}$$

Table 1. Proportions by Weight to Make 1 Cu.Ft. of Concrete

Maximum-size coarse aggregate, in.	Air-entrained concrete				Concrete without air			
	Cement, lb.	Sand, lb.	Coarse aggregate, lb.*	Water, lb.	Cement, lb	Sand, lb.	Coarse aggregate, lb.*	Water, lb.
⅜	29	53	46	10	29	59	46	11
½	27	46	55	10	27	53	55	11
¾	25	42	65	10	25	47	65	10
1	24	39	70	9	24	45	70	10
1½	23	38	75	9	23	43	75	9

*If crushed stone is used, decrease coarse aggregate by 3 lb. and increase sand by 3 lb.

Table 2. Proportions by Volume

Maximum-size coarse aggregate, in.	Air-entrained concrete				Concrete without air			
	Cement	Sand	Coarse aggregate	Water	Cement	Sand	Coarse aggregate	Water
⅜	1	2¼	1½	½	1	2½	1½	½
½	1	2¼	2	½	1	2½	2	½
¾	1	2¼	2½	½	1	2½	2½	½
1	1	2¼	2¾	½	1	2½	2¾	½
1½	1	2¼	3	½	1	2½	3	½

For example, a 4-in.-thick patio slab, 12 ft. wide and 15 ft. long, would require: $\frac{12 \times 15 \times 4}{12} = 60$ cu.ft. of concrete. A wall 3 ft. high, 10 ft. long, and 8 in. thick would require: $\frac{3 \times 10 \times 8}{12} = 20$ cu.ft.

The amount of concrete determined by the above formula does not allow for losses due to uneven subgrade, spillage, etc., so add 5 to 10 percent for such contingencies. In the case of the wall, the total amount of concrete required would be $20 + (0.10 \times 20) = 22$ cu.ft.

The quantities of material to buy can be calculated by multiplying the number of cubic feet of concrete (22 in this example) by the weights of materials needed for 1 cu.ft., given in Table 1. Assuming the wall will require air-entrained concrete and the maximum size of available aggregate to be ¾ in., the quantities of material needed would be as follows:

$22 \times 25 = 550$ lb. of cement
$22 \times 42 = 924$ lb. of sand
$22 \times 65 = 1{,}430$ lb. of gravel

Since it is generally impossible to recover all of the material, a 10 percent allowance should be made to cover normal wastage. It is preferable to have some material left over than to run the risk of being short of material near the end of the job.

The quantities of material needed should therefore be increased to:

$550 + (0.10 \times 550) = 605$ lb. of cement
$924 + (0.10 \times 924) = 1{,}016$ lb. of sand
$1{,}430 + (0.10 \times 1{,}430) = 1{,}573$ lb. of gravel

Since a U.S. bag of cement weighs 94 lb., you will need to buy $\frac{605}{94} = 6.4$ or 7 bags. A Canadian bag weighs 80 lb., so you will need $\frac{605}{80} = 7.5$ or 8 bags if you buy your cement in Canada. If air-entraining cement is not available, you will also need to obtain an air-entraining agent.

Aggregates are sold by the ton (2,000 lb.) or by the cubic yard (27 cu.ft.). Quantities of aggregates can be converted from pounds to cubic yards, or vice versa, by assuming a value of 90 lb. per cubic foot for the weight of sand and 100 lb. per cubic foot for the weight of coarse aggregate. Accordingly, 1,016 lb. of sand contains $\frac{1{,}016}{90} = 11.3$ cu.ft. or $\frac{11.3}{27} = 0.42$ cu.yd., and 1,573 lb. of gravel contains $\frac{1{,}573}{100} = 15.7$ cu.ft. or $\frac{15.7}{27} = 0.58$ cu.yd.

MEASURING THE INGREDIENTS

Ingredients must be measured accurately to ensure production of uniform batches of quality concrete. Ingredients may be measured by weight or by volume.

Measurement by weight is recommended because it is more accurate and hence produces greater uniformity from batch to batch. Also, it is easier to make adjustments in mix proportions when measuring by weight. A common bathroom scale is accurate enough for weighing the materials. Each ingredient should be weighed in a separate container. Three- to five-gallon galvanized steel pails or buckets are suitable. Remember to "zero" the scale with the empty container on it. After weighing each ingredient once, mark the level of the material inside the container. Subsequent batches may be measured by using this mark. The scale will no longer be required except to check the marks against the weight of material once or twice a day, or when the moisture content of the sand has changed.

Although less accurate, measurements may be made by volume if no scale is available. For example, a 1:2¼:3 concrete mix from Table 2 would be batched by measuring out 1 pail of cement, 2¼ pails of sand, 3 pails of coarse aggregate, and ½ pail of water. Take care when batching by volume not to overload the mixer. This will reduce mixing efficiency.

Adjusting for water in the sand. Dry sand is rarely available for concrete work. Sand used on most jobs contains some moisture which must be accounted for as part of the mixing water.

The proportions given in Table 1 are based on *wet sand* (Fig. 3), which is the condition of sand usually available. When squeezed in the hand, wet sand forms a ball and leaves no noticeable moisture on the palm. *Damp sand* (Fig. 4) falls apart when squeezed in the hand. *Very wet sand* (Fig. 5) forms a ball when squeezed in the hand and leaves noticeable moisture on the palm. This is the condition of sand exposed to recent rain.

If you are using damp sand, decrease the quantity of sand given in Table 1 by 1 lb. and increase the quantity of water by 1 lb. If your sand is very wet, increase the quantity of sand by 1 lb. and decrease the quantity of water by 1 lb.

The proportions given in Table 2 also are based on wet sand, but measurement by volume involves too many inaccuracies to justify making corrections for the moisture in damp or very wet sand. For example, moisture in sand causes an increase in volume known as bulking. The extent of bulking depends on the amount of moisture in the sand and its fineness. Dry sand can bulk to 1¼ times its volume when wetted. Accordingly, if you are measuring by volume, try to use wet sand.

MIXING THE INGREDIENTS

Proper mixing is an essential step in making good concrete. It is not sufficient merely to intermingle the ingredients. They must be thoroughly mixed so that cement paste coats every particle of fine and coarse aggregate in the mix. Concrete may be machine mixed or hand mixed.

Machine mixing. The best way to mix concrete is with a concrete mixer. It ensures thorough mixing of the ingredients and is the only way to produce air-entrained concrete.

Small mixers from ½- to 6-cu.ft. capacity can be rented or purchased. For extensive work around the home, it might pay to purchase a mixer. For the occasional small job, however, it is preferable to rent a mixer from your local rental service store or yard.

Mixers are powered by gasoline or electricity. The gasoline-powered mixer is more versatile in that it can be operated anywhere. The electric-powered mixer is quieter and simpler to operate, but requires an electrical outlet.

Mixer sizes are designated according to the maximum concrete batch in cubic feet that can be mixed efficiently. This is usually 60 percent of the total volume of the mixer drum. The maximum batch size is usually shown on an identification plate attached to the mixer. For proper mixing, never load a mixer beyond its maximum batch capacity. The choice of mixer size will depend on the extent of your project and the amount of concrete that you want to handle in any one batch. Keep in mind that to mix a 1-

Fig. 3 *(left). Wet sand*, which describes most sands, forms a ball when squeezed in your hand, but leaves no noticeable moisture on the palm. **Fig. 4** *(center). Damp sand* falls apart when you try to squeeze it into a ball in your hand. **Fig. 5** *(right). Very wet sand*, which describes sand exposed to a recent rain, forms a ball if squeezed in your hand and leaves moisture on the palm.

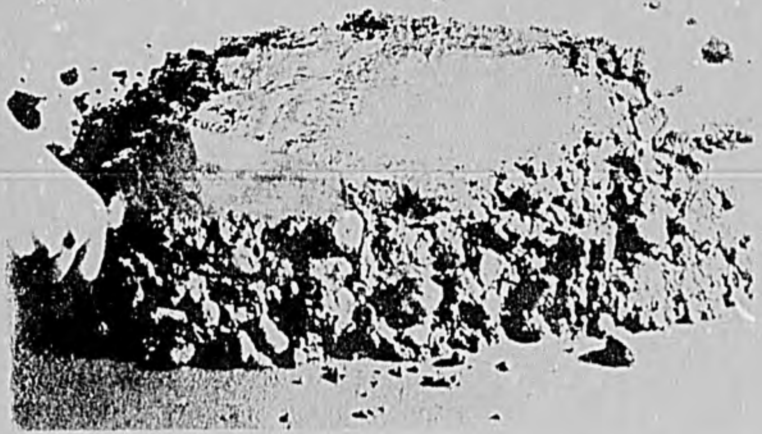


Fig. 6. A *workable mix* contains the correct amount of cement paste, sand, and coarse aggregate. With light troweling, all spaces between coarse aggregate particles are filled with sand and cement paste.

cu.ft. batch of concrete you will have to handle 140 to 150 lb. of materials.

For best results, load the ingredients into the mixer in the following sequence:

1. With the mixer stopped, add all the coarse aggregate and half of the mixing water. If an air-entraining agent is used, mix it with this part of the mixing water.
2. Start the mixer, then add the sand, cement, and remaining water with the mixer running.

After all ingredients are in the mixer, continue mixing for at least three minutes, or until all materials are thoroughly mixed and the concrete has a uniform color.

Concrete should be placed in the forms as soon as possible after mixing. If the concrete is not placed within 1½ hours and shows signs of stiffening, remixing for about two minutes may restore its workability. Discard the concrete if after remixing it is still too stiff to be workable. *Never add water to concrete that has stiffened to the point where remixing will not restore its workability.*

Mixing the trial batch. The proportions of sand and coarse aggregate from Table 1 are based on typical gravel aggregates. If these proportions do not give a workable mix with your aggregates, an adjustment will be necessary. The so-called trial batch will enable you to make these adjustments.

First make a batch of concrete using the proportions from Table 1. Discharge a sample of concrete from the mixer into a wheelbarrow or onto a slab and examine it for stiffness and workability. If this sample is a smooth, plastic, workable mass that will place and finish well, proportions used are correct and need no adjustment. The suitability of the sample can be judged by working the concrete with a shovel and smoothing it with a float or trowel. A good, workable mix should look like the sample shown in Fig. 6. The concrete should be just wet enough to stick together without crumbling. It should slide down, not run off, a shovel. In a workable mix there is sufficient cement paste to bind the pieces of aggregate together so that they will not separate when the concrete is transported and placed in the forms. There should be sufficient sand-cement paste to give clean, smooth surfaces free from rough spots (called honeycomb) when forms are stripped. In other words, there should be just enough cement paste to completely fill the spaces between the particles of aggregate and to ensure a plastic mix that finishes easily.

Fig. 7. This mix is *too wet* because it contains too little sand and coarse aggregate for the amount of cement paste. Such a mix would not be economical or durable and would have a strong tendency to crack.

Fig. 8. This mix is *too stiff* because it contains too much sand and coarse aggregate. It would be difficult to place and finish properly.

Adjusting the trial batch. If the trial batch is too wet, too stiff, too sandy, or too stony, it will be necessary to adjust the proportions of aggregates used in the mix.

If the mix is too wet (Fig. 7), it contains too little aggregate for the amount of cement paste. Return the sample to the trial batch, then weigh out about 5 to 10 percent more sand and coarse aggregate, depending on how wet the mix is. Add them to the trial batch in the mixer and mix for at least one minute. If the mix is still too wet, add some more sand and coarse aggregate until the desired workability is obtained. Record the total weight of added sand and coarse aggregate. In subsequent batches, use the original quantities of aggregate, but reduce the amount of water by 1 lb. for every 10 lb. of aggregate added to the trial batch.

If the mix is too stiff (Fig. 8), it contains too much aggregate. Reduce the amounts of sand and coarse aggregate in subsequent batches until the desired workability is obtained. Record the new weights of sand and coarse aggregate, and correct the weight marks in the batch cans according to the adjusted weights. To save a trial batch that is much too stiff to place, cement and water may be added in the proportion of 1 lb. water to 2 lb. cement. This will increase the amount of cement paste and make the concrete more workable. *Never add water alone to a mix that is too stiff.*

If the mix is too sandy (Fig. 9), decrease the amount of sand by 2 lb. and add 2 lb. of coarse aggregate. If it is still too sandy, leave out some more sand and add an equal weight of coarse aggregate in the next batch. Record the new weights of sand and coarse aggregate, and correct the weight marks in the batch cans according to the adjusted weights.

If the mix is too stony (Fig. 10), decrease the amount of coarse aggregate by 2 lb. and add 2 lb. of sand. If it is still too stony, leave out some more coarse aggregate and add an equal weight of sand in the next batch. Record the new weights of sand and coarse aggregate, and correct the weight marks in the batch cans according to the adjusted weights.

Your adjusted trial batch proportions are your final mix proportions and need not be changed again for future batches as long as your sand and coarse aggregate remain the same. If the moisture content of your sand changes, due to rain, for example, adjust the quantities of sand and water as explained under Measuring the Ingredients, page 4.

Hand mixing. For very small jobs, where the volume of concrete required is less than a few cubic feet, it is sometimes more convenient, though less efficient, to mix by hand.

Hand mixing is not vigorous enough to make air-entrained concrete, regardless of whether air-entraining cement or an air-entraining agent is used. Hand mixing, therefore, should not be used for concrete that will be exposed to freezing-thawing or de-icers.

Hand mixing should be carried out on a clean, hard surface or in a mortar box to prevent contamination by mud and dirt. A concrete slab makes a good working surface. The measured quantity of sand is spread out evenly on the slab. Then the required amount of cement is dumped on the sand and evenly distributed. Mix the cement and sand thoroughly by turning with a short-handled, square-end shovel until you have a uniform color, free from streaks of brown and grey. (Streaks indicate that the sand and cement have not been thoroughly mixed.) Next, spread this mixture out evenly over the slab and dump the required quan-

Fig. 9. This mix is *too sandy* because it contains too much sand and not enough coarse aggregate. It would place and finish easily, but would not be economical, and would be very likely to crack.

Fig. 10. This mix is *too stony* because it contains too much coarse aggregate and not enough sand. It would be difficult to place and finish properly and would result in honeycomb and porous concrete.

tity of coarse aggregate in a layer on top. The materials are again turned by shovel until the coarse aggregate has been uniformly blended with the mixture of sand and cement. After at least three turnings, form a depression or hollow in the center of the pile and slowly add the proper amount of water. Finally, turn all the materials in toward the center and continue mixing until the water, cement, sand, and coarse aggregate have all been thoroughly combined.

Prepackaged mixes. Jobs small enough for hand mixing can usually be done with convenient prepackaged concrete mixes. Building materials suppliers, hardware stores, and even some supermarkets sell prepackaged concrete mixes. All the necessary ingredients—portland cement, dry sand, and dry coarse aggregate—are combined in the bag in the correct proportions. Packages are available in different weights, but the most common sizes are 45 and 90 lb. A 90-lb. package makes ⅔ cu.ft. of concrete. All you do is add water and mix. Directions for mixing and the correct amount of water to add are given on the bag.

To ensure that you get good quality from prepackaged concrete mixes, the American Society for Testing and Materials has adopted Specifications for Packaged, Dry, Combined Materials for Mortar and Concrete (ASTM C387). This specification covers the quality of the ingredients, the strength of concrete obtained with the ingredients, and the type of bag in which the ingredients are packaged. ASTM C387 also requires that prepackaged concrete mixes meeting this specification be so identified on the bag. To obtain a quality product, make sure the prepackaged mix you buy contains a statement on the bag that it meets ASTM C387.

If the concrete will be exposed to freeze-thaw or deicers, prepackaged mixes must be machine mixed and must be made with air-entraining cement, or an air-entraining agent must be added to the mixing water.

As pointed out above, prepackaged mixes are most convenient for the very small job requiring only a few cubic feet of concrete. However, for larger jobs up to 1 cu.yd. (27 cu.ft.), you would be wise to compare the cost of using prepackaged mixes with the cost of buying the separate ingredients.

Cleaning the mixer. Soon after you finish using the mixer (before the concrete can harden), it should be thoroughly cleaned. To clean the inside of the mixer drum, add water and a few shovels of coarse aggregate while the drum is turning. Follow this by hosing with water. The thin cement film that builds up on the exterior parts of the mixer may be removed with vinegar. Concrete that builds up inside the mixer drum requires scraping and wire brushing for removal. Heavy hammers or chisels that might tear up the drum and blades should not be used. Remove stubborn buildup with a solution of 1 part hydrochloric acid (muriatic acid) in 3 parts of water. Allow 30 minutes for penetration, then scrape or wire brush and rinse with clear water.

Hydrochloric acid is hazardous and toxic and requires adequate safety precautions. Skin contact and breathing of fumes should be avoided. As a general precautionary rule, rubber or plastic gloves and chemical safety goggles should be worn. If the acid is used indoors, adequate ventilation should be provided. Follow the storage and handling precautions stated on the label of the acid container.

Dry the mixer drum thoroughly to prevent rusting and store the mixer with the opening of the drum pointing down. Do not apply oil to the inside of the drum unless the mixer is to be stored for an extended period of time. Thoroughly wipe off the oil before using the mixer again, as it may adversely affect the quality of the concrete.

Caution: Avoid prolonged contact between unhardened (wet) cement or concrete mixtures and skin surfaces. To prevent such contact, it is advisable to wear protective clothing. Skin areas that have been exposed to wet cement or concrete, either directly or through saturated clothing, should be thoroughly washed with water.

PORTLAND CEMENT ASSOCIATION

An organization of cement manufacturers to improve and extend the uses of portland cement and concrete through scientific research, engineering field work, and market development.

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