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***Cover photograph*:** Lack of proper maintenance resulting in near loss of structure.

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TYPES AND MAINTENANCE OF PIPE SYSTEMS

by: Jim Keith, Program Analyst, Bureau of Reclamation, 84-57000

General

The Bureau of Reclamation (Reclamation) has designed and installed over 3,500 miles of pipe. Although most of this pipe has been for irrigation distribution systems, we also have worked on large transmission pipelines and municipal and industrial (M&I) city systems. These pipes have ranged in inside diameters from 2 inches to 21 feet. The internal pressures have been from zero pressure (partial flow) to 825 feet of head (358 pounds per square inch [lbs/in^2]). Although most of our pipelines have been buried, we have also worked on aboveground systems such as penstocks. The buried pipes have had earth covers that ranged from 3 to 35 feet. With such wide ranges in design requirements and water district pipe preferences, Reclamation has used the following types of pipe: asbestos-cement, ductile iron, embedded cylinder prestressed concrete, lined cylinder prestressed concrete, monolithic cast-in-place, noncylinder prestressed concrete, polyethylene (PE), polyvinyl chloride (PVC), pretensioned concrete cylinder, reinforced concrete cylinder, reinforced concrete pressure, fiberglass, and steel.

Pipeline Systems Terminology

Pipeline – This generic term can be applied to any pipe system. In Reclamation, this usually refers to a pressurized pipe system that supplies water for irrigation or municipal purposes. Reclamation normally works on pressurized pipe systems, except for drainage applications.

Siphons – This type of pipe is usually associated with a canal. Siphons are used to cross gullies or washes. The use of the term “siphon” is actually a misnomer, as they are really inverted siphons, meaning that the pipe does not go higher than the hydraulic head available.

Culverts – This term applies to pipe that is used to pass runoff water under another structure. These are designed for very low or no pressure. These types of pipes are usually corrugated PVC or corrugated PE, corrugated metal, or concrete because of the low cost for these materials.

Laterals – This term is usually associated with water distribution systems. Canals or pipelines are both commonly called laterals.

Municipal and Industrial (M&I) – This type of system supplies large volumes of water from one point to another. Typically, the water is supplied to cities or other large users. There are normally only a small number of deliveries associated with an M&I system.

Distribution – This system delivers water to a large number of locations. Distribution systems have smaller flow rates than what are used in M&I systems. These systems generally supply water to farm units on Reclamation projects and homes in city systems.

Gravity – Water flows through this type of pipeline system by static pressure. The static pressure can be supplied by a tank, regulating reservoir, or canal water surface, which are generally located at a high point. The delivery water surface elevations at delivery points are below the source water surface elevation.

Pumped – The pressure in this type of system is supplied by pumps at the beginning of the pipeline or anywhere in the system. In pumped systems, the delivery water surface elevations at delivery points may be above the pump sump water surface elevation.

Pipe Terminology

These are common terms associated with pipes:

Pipe – Pipe is defined as a seamless tube conforming to the particular dimensions commonly known as standard pipe size (from American Society for Testing and Materials [ASTM] B-251-557).

Springline – The springlines are the sides of the pipe at the horizontal centerline or diameter of the pipe.

Invert – The invert is the bottom inside of the pipe.

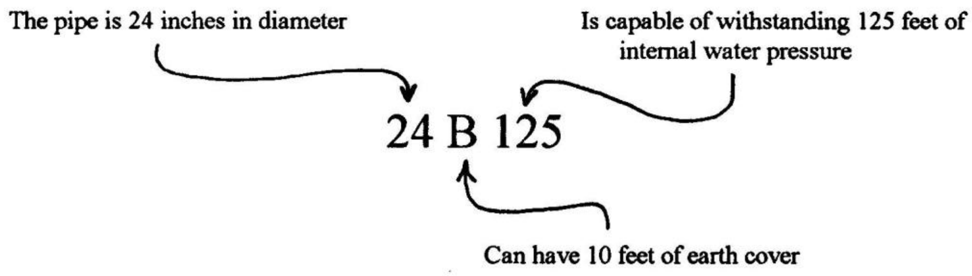
Centerline of Pipe – The centerline is the vertical center of the pipe in plan or the horizontal center in profile.

Crown – The crown is the inside top of the pipe.

Haunch Area – The haunches of the pipe are the outside areas between the springlines and bottom of the pipe.

Pipe Designations

Reclamation plan and profile drawings show diameter, cover class, and pressure class of the pipe. This is usually shortened to 24 B 125, for example. The 24 is the diameter in inches. The B indicates a maximum cover of 10 feet (A represents a maximum cover of 5 feet, C has a maximum cover of 15 feet), etc. The 125 represents the pressure in feet (this number is sometimes expressed in lbs/in^2).



Pipe units usually have various information printed on the inside or outside of the pipe. Other information may be shown on the pipe unit indicating what AWWA or ASTM standard was used to manufacture the pipe. Information on pipe marking required is discussed under pipe types.

Type of Pipe Used in Irrigation Systems

Once the type of pipe system desired has been determined, the type of pipe to be used is the next important question to be resolved. Selection of the type of pipe or pipes to be used in the system is made during the designing stage by the designing engineer and the user. The best type of pipe for the conditions encountered would be provided. For diameters 24 inches and smaller, PVC is a popular choice for pressure systems because the pipe is corrosion resistant and relatively lightweight.

For design purposes, Reclamation divides the pipe types into rigid and flexible categories:

Rigid Pipe – Designed to transmit the load through the pipe wall to the foundation material or earth. These loads include the earth load, live load, water load, and the weight of the pipe. We assume the foundation reaction is distributed over a 90-degree (°) bedding angle. Our specifications require that the compacted backfill (embedment) be placed to 0.37 outside diameter (O.D.) to ensure a 90° bedding angle for rigid pipe.

Flexible Pipe – Designed such that the earth load and live load are transmitted to the soil at the sides and bottom of the pipe. The soil at the sides of the pipe has to be strong enough to hold the sides of the pipe in place without exceeding the long-term deflections mentioned later. Flexible pipe can withstand these long-term deflections without damage to the pipe wall. Reclamation specifications require that the compacted backfill (embedment) be placed to 0.70 O.D. to ensure that good soil support is achieved at the sides of the flexible pipe.

The types of pipe currently used by Reclamation are listed below:

Rigid and Flexible Pipe Types

	Diameter (inches)	Head (feet)	Standard Manufacturing Lengths (feet)	Design Standards
Rigid Types				
Unreinforced Concrete Pressure (UCP)	6-24	25-30	2.5-4	ASTM C118
Reinforced Concrete Pressure (RCP)	12-108	25-125	8-24	AWWA C302, ASTM C361
Reinforced Concrete Cylinder (RCCP)	72-180	25-600	12-24	AWWA C300
Monolithic Cast-In-Place Concrete (MONO)	90 and larger	25-125	12-25	NONE
Flexible Types				
Steel (ST)	4 and larger	All	20-50	AWWA C200
Fiberglass (RTR)	8-108	25-500	20	AWWA C950
Ductile Iron (DI)	6-64	25-800	20	AWWA C150
Polyethylene (PE or HDPE)	4-63	25-450	20-50	AWWA C906
Polyvinyl Chloride (PVC)	4-12 14-48	25-400 25-525	20 20	AWWA C900 AWWA C905
Pretensioned Concrete Cylinder (PT)	12-66	25-700	24-40	AWWA C303

Flexible Pipe Type Descriptions

Pretensioned Concrete Cylinder Pipe

This type of pipe is a composite design; the basic element of the pipe is a welded steel cylinder with steel joint rings welded to each end. The cylinder is lined with centrifugally placed mortar. Continuous reinforced rod is helically wound, under controlled tension, around the lined cylinder. A mortar coating is then placed on the outside by means of high-velocity impaction.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal size and class (e.g., 36 B 225)
(2) Name or trademark of manufacturer
(3) Date of manufacture and number in sequence of production
(4) Type of cement and class of pozzolan (if used)

Polyvinyl Chloride Pipe

PVC plastic resin can be repeatedly softened to a plastic state by the application of heat and hardened to a solid state by cooling. This type of pipe is manufactured by extruding the heated, molten plastic through a forming die to obtain the cylindrical shape of the proper diameter and wall thickness. The pipe is then immediately cooled and cut to the proper length.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) The nominal size and O.D. base (e.g., 24CI)

(2) AWWA C900 or C905

(3) Standard Dimension Ratio (SDR) or Dimension Ratio (DR) (e.g., SDR41 or DR18)

(4) Date of manufacture and shift designation

(5) Name or trademark of manufacturer

Steel Pipe

Steel pipe can be manufactured in practically any size or pressure rating. The pipe is manufactured by rolling sheet steel (either flat plate or continuous roll) into a cylindrical shape and welding the edges of the sheet together. The inside of the pipe is either mortar lined or painted with coal-tar epoxy. The outside is either mortar coated or tape wrapped.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Serial number or other identification
(2) Nominal size and class (e.g., 36 B 225)
(3) Name or trademark of manufacturer
(4) Date of manufacture and number in sequence of production

Ductile Iron Pipe

This type of pipe is manufactured by introducing a charge of molten iron into a rapidly spinning mold. The centrifugal force due to the spinning process forms the molten iron into a cylinder of uniform thickness, which is determined by the volume of the molten charge. After cooling and annealing, a thin cement mortar lining is applied to the inside of the pipe. The inside and outside are then painted with asphalt. This type of pipe is installed with a continuous encasement of polyethylene.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal pipe size, 24 inches
(2) Pressure class, PC 150
(3) AWWA C151
(4) Date of manufacture
(5) Name or trademark of manufacturer

Fiberglass Pipe

This type of pipe is sometimes referred to as Reinforced Thermosetting Resin (RTR) pipe. The pipe is composed of continuous fiberglass filaments in a polyester resin matrix. The glass strands are wound on a rotating mandrel in a helical fashion until the required wall thickness is obtained. The helical angle, which varies among manufacturers, provides longitudinal as well as circumferential strength.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal pipe size, 24 inches
(2) Pressure class, PC 150
(3) AWWA C950

(4) Stiffness class (e.g., PS72)
(5) Date of manufacture and shift designation
(6) Name or trademark of manufacturer

Polyethylene Pipe

This type of pipe is manufactured by extruding heated, molten polyethylene through a forming die to obtain the cylindrical shape of the proper diameter and wall thickness. The pipe is then immediately cooled and cut to the proper length. Joints are made by heating the pipe ends and butt fusing the two pieces together.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal size and O.D. base (e.g., 24IPS)
(2) PE material (e.g., PE 3408)
(3) Pressure class (e.g., PC 150)
(4) Dimension Ratio (e.g., DR25)
(5) AWWA C906
(6) Date of manufacture and shift designation
(7) Name or trademark of manufacturer

Rigid Pipe Descriptions

Unreinforced Concrete Pipe

This type of pipe is used for irrigation and drainage applications with low pressures, under 25 feet of head. The pipe consists of a unreinforced concrete shell with concrete joints.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal size and class, O.D. 24B25
(2) Name or trademark of manufacturer
(3) Date of manufacture and number in sequence of production
(4) Type of cement and class of pozzolan (if used)

Reinforced Concrete Pressure Pipe

This type of pipe is commonly called bar pipe or precast pipe and consists of reinforcement cages placed in a concrete shell to resist bursting pressures and external earth loads. The joints may be either steel or concrete. Generally, this pipe type is used where the headclass requirements are 125 feet or less.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal size and class, O.D. 36B125
(2) Name or trademark of manufacturer
(3) Date of manufacture and number in sequence of production
(4) Type of cement and class of pozzolan (if used)

Reinforced Concrete Cylinder Pipe

This type of pipe was developed to handle higher internal heads than reinforced concrete pressure pipe. This pipe consists of a steel cylinder with steel joint rings attached and around which a cage of reinforcing steel is placed. The cylinder and cage assembly comprises the inner layer of reinforcement, a second or outer reinforcement cage is provided, and concrete is cast around the reinforcement layers to form the pipe wall. Generally, this pipe type is used where the headclass requirements are greater than 125 feet.

Marking

Each pipe unit shall be clearly and permanently marked on the interior surface with:

(1) Nominal size and class, O.D. 72B225
(2) Name or trademark of manufacturer
(3) Date of manufacture and number in sequence of production
(4) Type of cement and class of pozzolan (if used)

Monolithic Cast In-Place Concrete Pipe

This type of pipe, which is constructed in place like a reinforced concrete structure such as a bridge or building, is similar to reinforced concrete pipe and generally is used for larger diameter pipe.

Pipe Joints

Reclamation has found by experience that the pipe joint is one of the most important features in a pipe system. A good pipe joint must be flexible enough to permit longitudinal movement due to temperature changes in the water and to wetting and drying of the pipe, as well as vertical adjustments due to settlement that sometimes occurs due to the application of irrigation water to adjacent lands.

Low-head pipe (UCP) used on early Reclamation pipe distribution systems utilized tongue-and-groove precast concrete pipe with a mortar-banded, rigid-type joint. Pipelines laid with this joint had a low first cost and, generally, a higher maintenance cost, as well as increased water loss through the life of a project. This type of joint is now only used occasionally by Reclamation.

Figure 1 shows outlines of the most commonly used concrete pipe joints. The concrete or steel element containing the gasket is constructed and shaped in such a way that the gasket is contained in a groove and does not support the weight of the pipe. When the spigot is inserted into the bell end, the gasket is compressed into the groove, forming a watertight seal.

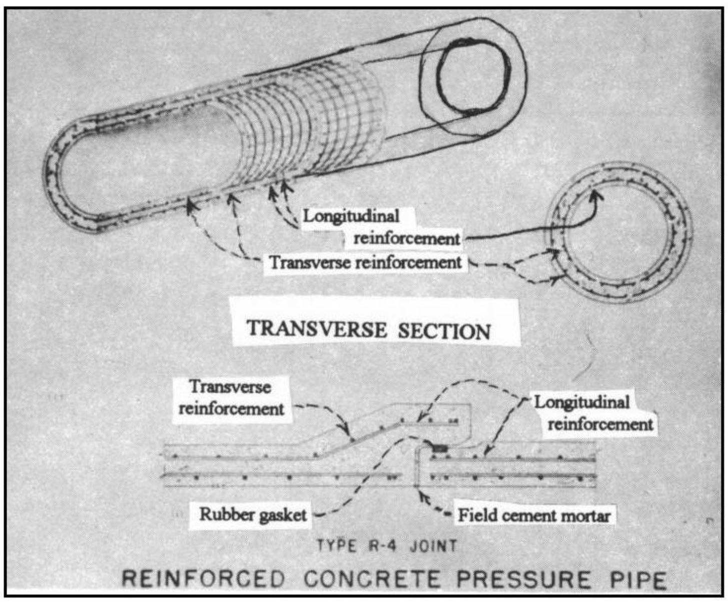


Figure 1.—Reinforced concrete pressure pipe.

Internal Loads

The internal loads or pressures include the steady-state and transient pressures. The steady-state pressures are determined by calculating the hydraulics of the pipe system under normal operating conditions. Transient pressures are determined by examining abnormal conditions such as power failure and some normal conditions such as valves opening and closing and pumps stopping and starting.

Corrosion

Corrosion is the big enemy of pipes containing ferrous materials. Requirements for controlling external corrosion on buried pipe alternatives containing ferrous elements can be determined from corrosion surveys. These surveys should determine the soil resistivities and stray currents along the pipeline alignment as well as an assessment of corrosion history in the area. Auxiliary corrosion control requirements should be specified in accordance with the indicated resistivities tabulated below.

Corrosion Prevention Criteria and Requirements

Pipe Alternative	External Protection (Primary/ Supplemental)	Soil Resistivity – 10% Probability Value (Ω-m)		Corrosion Monitoring System	Cathodic Protective System
		Irrigation	M&I		
Ductile iron	Polyethylene encasement[1]	>15 ≤15	>30 ≤30	X X	 X
	Bonded[2] dielectric	>10 ≤10	>20 ≤20	X X	 X
Pretensioned	Mortar/coal-tar epoxy	>20 ≤20	>40 ≤40	X X	 X
	Mortar/coal-tar epoxy	>15 ≤15	>30 ≤30	X X	 X
Reinforced concrete	Concrete	>20 ≤20	>40 ≤40	X X	 X
	Concrete/coal-tar epoxy	>15 ≤15	>30 ≤30	X X	 X
Steel	Mortar	>20 ≤20	>40 ≤40	X X	 X
	Mortar/coal-tar epoxy	>15 ≤15	>30 ≤30	X X	 X
	Bonded[2] dielectric	>10 ≤10	>20 ≤20	X X	 X

[1] Applicable to pipe with corrosion allowance, 24-inch inside diameter maximum, and 150 pressure class maximum.
[2] Bonded directly to metal to be protected.

Appurtenant Structures

Air Valves

Air valves are used in pipeline systems to remove any air that may get trapped inside the pipeline and, more importantly, for filling and draining the pipeline. Generally, air valves are placed at high points along the pipe profile. Reclamation uses a combination air and vacuum valve in most cases to allow air into the pipeline during draining and to expel air during filling. The size of air valve controls the amount of time required to fill and drain a pipeline system.

Blowoffs

Blowoffs are required on pipelines to allow water to be emptied for operation and maintenance requirements, inspection, or repair. Depending on the pressure head on the blowoff valve, orifice plates or some type of energy dissipater may be required to prevent damage to the ground where the water exits.

Drains

Drains are similar to blowoffs, but are mainly used on irrigation systems for small-diameter pipes (less than 27 inches). The water is often emptied into a gravel pocket buried below ground when draining the pipe to daylight would be cost prohibitive.

Manholes

Manholes are provided in pipelines 27 inches in diameter and greater. The manholes provide access as well as ventilation into the pipeline for inspection or repair. Typical spacing of manholes is every ½ mile for irrigation systems and every 1,000 feet for M&I and city systems. Manholes should be sized as large as possible for large-diameter pipes when ladders would be required for access.

Surge Relief

Transients or water hammer waves occur in pipelines when the flow velocity changes. Generally, these changes are due to valve or pump operations. Various methods are used to combat these transients. Common methods for the control of transients are surge tanks, valve closure speeds, flywheels, realignment of proposed pipe profiles, or air chambers. Gravity system transients can usually be controlled by slowing the valve closure times. Hydraulic transient analysis typically includes upsurge and downsurge considerations.

In pump systems, one method to reduce downsurge problems is to place a surge tank of equal diameter as the pipeline to dissipate the energy in the standpipe. The disadvantage of this system is that the surge stand may need to be several hundred feet tall for high-pressure systems.

Air chambers are also used for the control of transients. An air chamber consists of a pressure vessel that is partially filled with water and compressed air. The water is supplied to the pipeline during a downsurge, and the compressed air acts as a cushion when an upsurge occurs.

Quick opening valves are sometimes used to relieve upsurge pressure on smaller lines or turnouts. A typical example of this type is a Grove valve, which uses a rubber bladder held in place by compressed nitrogen until a surge opens the valve. The bladder closes after the surge has passed, and the amount of water spilled is generally small.

Delivery Structures

In distribution systems, turnouts are used to deliver water from the main line to individual users. A delivery structure is usually constructed to provide pressure reduction, flow measurement and rate of flow control, or isolation. These are accomplished by using a pressure reducing valve, a flowmeter, an orifice plate that limits the amount of water that can be taken through the delivery, and a butterfly valve.

Thrust Restraint

When a pipeline makes a bend, tapers from one pipe diameter to another, or dead ends, some form of restraint is required to keep a pipe with unrestrained joints from moving and leaking. This can be accomplished in different ways.

Earth blocking, which consists of compacting an area of soil behind the pipe or fitting is generally used for small diameters and low-pressure systems. Concrete blocking or concrete encasement placed around the pipe can prevent movement. Concrete blocking transfers the thrust on the pipe to an area of concrete that develops the passive resistance of the adjacent soil. Concrete encasement uses the weight of the concrete and soil frictional resistance to resist thrust. Combinations of the two types of concrete thrust restraint have been used. Concrete should never be placed over flexible joints in high-pressure systems due to the possibility of leakage at the joint and the high cost of repair.

Concrete collars are used to resist the thrust at tapers or dead ends. Collars are similar to concrete blocking, except that the concrete encircles the pipe.

Another method is to tie the pipe joints on either side of the bend with welding, mechanical joints, or some other restraint. This enables the designer to take advantage of the earth weight above the pipe in conjunction with the frictional resistance of the soil to resist the thrust.

Debris Removal

Moss screen or trashrack structures are installed at the inlet to pipelines from canals or reservoirs and pumping plants.

Figure 2 is a picture of a moss screen and recirculating pump structure at the head of a lateral in the Ivanhoe Irrigation District. This part of the equipment is the traveling moss screen structure. The source of water is the Friant-Kern Canal, which runs adjacent to the structure. The screen is similar to an endless belt and is self cleaning. The water in a pipe system must be fairly clean; otherwise, the flow measurement meters and valves will get fouled up. On the downhill side of the canal, there are usually some parcels of land near the canal that are too high to be delivered to by gravity. Small, low-head pump systems are used to get water to these lands. The vertical stand is a recirculating stand for the low-head pumps set on the deck of the structure. If more water is being pumped than is being delivered to the farmers, the excess water goes into the overflow on the stand and back into the pump sump structures.

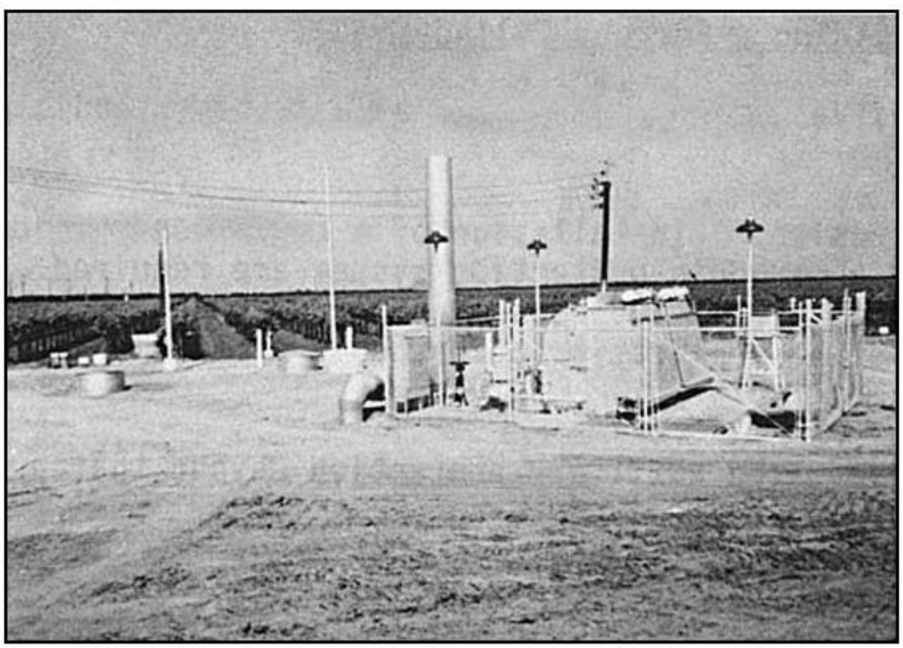


Figure 2.—Moss screen and pumping plant, Ivanhoe Irrigation District, California.

In a pipe distribution system, the pipe represents about 70 to 80 percent of the cost. The appurtenances, such as moss screens, pumping plants, valves, meters, and other appurtenances make up the remainder.

Installation

For any of the various pressure pipes, it is most important that care be taken while the pipe is being installed. This includes the bedding and backfilling afterward. Many of the problems that occur later in operating a system are caused either by careless or incompetent work during the initial installation.

The joints, with their rubber gaskets, must be carefully installed, and the pipe must have a uniform bearing for its full length. The bedding material must be carefully placed in accordance with the requirements of the specifications. Special attention must be given when pipe enters or leaves a structure or is connected to a valve so that differential settlement will not take place, causing breaks that are extremely difficult to repair.

Maintenance

Anyone operating a new full-pressure system must staff and train capable people to protect the system and the water users' interests.

After construction is completed, the designers stress to the operators a

"CARDINAL RULE"

**FILL SLOWLY – OPERATE VALVES SLOWLY –
SHUT DOWN SLOWLY**

The importance of this "Cardinal Rule" may be understood from a brief explanation of the extreme pressures that can be generated by water hammer. The definition of water hammer is hydraulic transients or sudden upsurges or downsurges of the total pressure in a piping system due to changes in velocity of the fluid carried by the system. Transient pressures build up due to opening or closing valves to rapidly changing valve settings (accidental or planned), starting or stopping pumps, and unstable pump turbine characteristics.

The most critical period during the life of the pipeline is the initial filling and testing. Extreme caution should be used during this time period. During the filling period, a safe procedure is to not allow the velocity to exceed 0.25 foot per second (Reclamation criteria).

Opening and closing valves too rapidly can literally blow pipe out of the ground and cause extensive damage. The same result can occur if air is trapped in pipelines by excessively rapid filling and failure to vent all air from the system. Close observation of air valves during draining and filling and adherence to Designers' Operating Criteria in the operation of valves, pumps, and control facilities is absolutely necessary to prevent damage. Avoiding sudden changes in velocity will generally avoid serious water hammer surges.

In a warm, non-freezing climate, preventive maintenance on the pipes themselves consists of keeping them full of water at all times during the non-irrigation season. In a cold, freezing climate, all the pipes must be drained or buried below the frostline and kept empty during the cold months. This is, of course, not possible on M&I systems, which operate year round or on pipeline systems located in a flood plain, which may cause the pipe to float out of the ground. For these systems, freeze protection is included in their design, and some flow should always be maintained to combat freezing. If conditions have changed since the system was designed and flows cannot be maintained, the system must be protected from freezing, especially the air release valve and pressure reducing valve. One district in the Pacific Northwest Region has installed an antifreeze-type solution in the air release valve to prevent it from freezing, similar to those used for mobile homes and RV campers.

During the non-irrigation season, large-diameter pipe should have protective barriers placed at the inlet and outlet ends to prevent people and vehicles from entering the pipelines. Small pipelines should also be protected to prevent rodents from entering the lines during the non-irrigation season. Siphons under roads should also be protected, especially if they are left full of water. Protective barriers should be placed at each end to prevent small children or animals from entering the structures.

Periodic inspections of large-diameter pipe interiors and exteriors and necessary repairs to the coatings must be made when needed. Culverts under canals should be inspected to determine if there are any misalignment cracks or if seepage is occurring.

Low-head, irrigation-type gate valves can require a considerable amount of maintenance. Broken gate leaves, arches, and stems are not uncommon, and replacement parts are not always from the same pattern, or the valve cannot be adjusted to stop leakage. The trend for replacement is toward a higher class valve with removable seats.

Most irrigation districts use butterfly valves instead of gate valves on pump installations. Operating personnel report that butterfly valves are easier to throttle, are providing better service, and are cheaper to purchase.

Pipeline Leaks – Causes and Repairs

Principal causes of leakage in precast concrete pipes (reinforced or unreinforced) are broken backs or bellies, joint failures, broken collars, splits, temperature cracks, and settlement at structures. Broken backs or bellies (circumferential cracks) can result from improper handling during installation, excessive loading from backfill or traffic, settlement or heave, and other causes. These are the most commonly experienced leaks that can occur in precast concrete pipe.

Joint failures can result from rolled or pinched rubber gaskets or from cracked bells or spigots. These can occur as a result of improper installation, settlement or heave, or excessive loading under some conditions. Joint failures commonly are more difficult to repair than circumferential cracks.

Splits, which are longitudinal cracks, are sometimes caused by the pipe expanding in length either from warming or absorption of moisture. Splits occur more often in cast-in-place pipes than in precast pipes. Precast pipe can be split by improper operation (opening or closing valves too fast, malfunction of pump controls, etc.), which results in exceeding design pressures.

Temperature cracks are most prevalent in unreinforced concrete pipe, but can cause trouble in reinforced pipes as well. These cracks take place when abnormally cold water is introduced into the pipes. The pipes contract and literally pull themselves apart. The cracks are usually transverse and will vary in width from hairline to ¼ inch. The possibility exists that temperature cracks are aggravated by laying the pipe in extremely hot weather without sufficient protection. It may also be true that temperature cracks are mistaken for broken backs or vice versa.

Uncontrolled corrosion can cause serious leakage of precast concrete pipe containing a ferrous cylinder. If undetected, corrosion can completely destroy the cylinder and reinforcing rods, leaving only the mortar lining to carry the water under pressure. Such corrosion can require extensive repair and may require replacement of entire sections of pipe.

In low-head systems, it is sometimes difficult to locate actual leaks or even to know a leak exists. Minor leaks may be more accurately described as seeps with moisture never reaching the ground surface. Under such conditions, the leakage would be considered as a pipeline loss much the same as leakage through cracks or joints in concrete-lined open ditches.

Repair would be attempted only if losses became excessive or damage to the foundation resulted. In some cases, particularly where pipelines traverse steep slopes, water from leakage may travel underground through the pipe trench and reach the surface considerable distances away from the actual leak. A small hand soil auger sometimes is useful in locating the origin of the water.

Among various ways to stop pipeline leaks, the introduction of material into a pipeline in operation to act as a sealant for small cracks is quick and easy. One of the earliest sealants used was horse manure. Today, sawdust is sometimes used. Sawdust, flour, and coarser ground sawdust are mixed with water and pumped into the line. Naturally, these procedures cannot be used on M&I systems and, in any case, are only temporary repairs. If the water is removed from the lines, chances are they will leak again when refilled.

The introduction of anhydrous ammonia (NH_3) appears to have a great deal of promise. The success of the system depends on the precipitation of calcium carbonate when ammonia is introduced. Unfortunately, the action does not occur with all waters. Reclamation initiated an investigation of ways and means of introducing other materials into water along with ammonia to promote precipitation. A report of this method has been published in Release No. 67 of Reclamation's *Operation and Maintenance Bulletin*.

A method commonly used to repair transverse broken backs or bellies in irrigation and reinforced concrete pipe is to chip or chisel the crack to form a 1/2- to 3/4-inch wide and deep V-notch. The notch is thoroughly cleaned by a wire brush or possibly sandblasting. An epoxy-based compound or mortar is troweled into the notch. The exterior of the notch is troweled to form a relatively uniform surface. Sheet rubber is then wrapped around the crack. The sheet rubber generally has a Shore durometer rating of from 30 to 40 compared to approximately 55 for the rubber gasket material. The sheet rubber is covered with a thin metal band and cinched up using narrow steel bands. After cleanup and drying of the area, the foundation is compacted, and an unreinforced concrete encasement is placed around the repair. For added protection, a concrete cradle is placed under the pipe approximately 18 inches on each side of the encasement.

Commercially available pipe repair clamps can often be used, without the need for chipping and caulking, where the circumferential crack occurs in pipe with a smooth concrete surface. These clamps can often be installed without taking the line out of service and utilize bonded waffle-surfaced rubber, which will effectively seal the leak permanently. Placement of a mortar covering over the metal material of the clamp is recommended.

Commercial clamps become extremely expensive for pipe diameters of 30 inches and larger, and some success with repairing circumferential cracks in large-diameter pipes has been experienced using locally fabricated clamps. Normally, 3/16-or 1/4-inch steel plate is rolled to the required diameter in two or three sections, depending on the size of pipe involved. These are installed over pads of "camel-back" rubber similar to that used for vulcanizing tires.

Rods or straps encircling the pipe and clamp are used for tightening. Again, a mortar coating is applied after completion of the repair. These clamps have the distinct advantage of maintaining flexibility while avoiding the excessive weight imposed by a concrete collar or encasement. As with any type repair, replacement of embedment to the original specification requirements is important to prevent future problems.

Joint failures can sometimes be repaired by caulking the interior of the pipe joint with a mastic material that maintains its flexibility indefinitely. (This type repair is useful at low-line pressure where easy access to the pipe interior is available.) Various types of field-fabricated clamps to reinforce and/or encase broken bells or spigots have been attempted, but no great success has been experienced with repairing these types of pipeline leaks. Encasement of the joint in a concrete collar is sometimes necessary, although not considered desirable.

Rubber-gasketed joint leaks caused by pinched gaskets can also sometimes be stopped under pressure by caulking with lead wool from the outside. If the joint moves after caulking, there is a good possibility that eventually the joint will leak again. “Freezing” the joint by placing concrete encasement after caulking often may cause shearing next to the encasement and should be avoided if possible. However, some districts have been successful with this method.

Repair of pipes containing a steel cylinder may sometimes be made by welding, either using partial or complete “butt-strap” closure sections or a commercially available repair collar. In some cases, replacement of complete sections may be the most economical and most desirable method of repair.

Some districts have arrived at the conclusion that one cannot affect a permanent cure for leaks in a mortar-jointed concrete pipeline having to operate under low water temperatures. These districts are replacing their poor lines with rubber-gasketed pipe of concrete or PVC (plastic pipe), whichever is the most competitive on a year-to-year basis.

Maintenance of Appurtenances

All air valves should be examined regularly to ensure that they function properly. Air valves that do not operate regularly can stick shut and fail to operate when needed. If the hydraulic pressure at an air valve location is low, the air valve may not seal properly, and continued leakage will damage the seating surfaces. During drainage and refilling, air valves should be checked for proper operation and to be sure that all air is exhausted after the system is filled. If gate valves are used below the air relief valve, you may want to remove the wheel from the valve stem so unauthorized closures will not occur.

Blowoff valves should be operated periodically to ensure the valves will function when needed.

Backfill adjacent to air valves and blowoff structures and insulation on the underside of covers must be adequately maintained to prevent freezing. Whenever a repair is made that requires removal of insulation from an air valve, the insulation should be properly replaced upon completion of the repair.

Maintenance and necessary repair of other concrete structures should be performed as needed. Leakage through tank or structure walls should be stopped and repairs made to prevent spalling and deterioration of the concrete. Metalwork should be painted regularly, and grounding systems, as well as other protective features, should be maintained in satisfactory condition. If backfill material is removed from the valve enclosure, it should be replaced to provide insulation.

When provided, corrosion monitoring facilities should be serviced and pipe-to-soil potentials measured regularly. Test stations (including anode sites) should be measured regularly and depleted anodes replaced. Periodic review of all corrosion monitoring readings by a knowledgeable engineer is very important to ensure that corrosion does not gain an insurmountable advantage and that the need for corrective or preventive measures is determined early.

CONCRETE REPAIR AND MAINTENANCE

by: Kurt VonFay and Rick Pepin, Bureau of Reclamation, Technical Service Center, Materials Engineering and Research Laboratory, 86-68180

Introduction

Management of water systems is a field that is very broad. Many disciplines in the technical and administrative communities are called upon to function either independently or jointly for the proper operation and maintenance of complex water works.

Many water systems contain structures built with concrete. Some concrete may last 100 years without any need for repair, while other concrete may need repair as soon as the forms are removed. It is often said (but too often forgotten) that the best material for concrete repair is concrete. New concrete used for repairs will usually be more compatible with the old concrete in strength, thermal expansion, modulus of elasticity, and permeability than other repair materials. Modern, more expensive materials should be used only after it has been determined that ordinary Portland cement concrete will not be an effective repair material. Making this decision requires knowledge of repair materials and their strengths and limitations.

The fact that repairs are required generally implies older technology concrete or a failure in either design, materials, or workmanship. Although you who are attending this workshop likely had no influence on the design or construction of the structures requiring repairs, you may have responsibility for assuring the continued safety, structural integrity, and operating efficiency of the aging structures under your jurisdiction.

Concrete Maintenance

This session discusses both concrete repair and concrete maintenance. Proper maintenance can avoid or postpone the need for major concrete repairs. When we think of maintenance, we think of lubricating machinery, painting wood and metal, and replacing worn parts; but too often, concrete is thought to be maintenance free.

Those responsible for the operation and maintenance of these facilities and structures need to understand that, with respect to concrete, there is no such thing as economical, deferred maintenance. Failure to promptly provide proper maintenance will simply result in very expensive repairs or replacement of otherwise useful structures (figure 1).

Figure 1.—Lack of proper maintenance resulting in near loss of structure.

A good maintenance program will involve regularly scheduled inspections. Suspect areas should be monitored. Photographs and notes should be collected and stored to establish a record that can be reviewed at a later date.

Maintenance for concrete typically consists of activities to keep water out of the concrete. Many times, water and some of the dissolved minerals it carries can damage concrete. Usually, some type of sealant, coating, or overlay is used, but other approaches can be used as well. Freezing and thawing tests of concrete specimens protected by a variety of concrete sealing compounds and coatings, including linseed oil, fluosilicates, epoxy and latex paints, chlorinated rubber, and waterproofing and penetrating sealers, have been performed in Bureau of Reclamation (Reclamation) laboratories. These tests indicate that proprietary epoxy formulations, siloxane and silane formulations, and the high molecular weight methacrylate formulations clearly excel in resisting deterioration caused by repeated freezing and thawing in the presence of water. None of these formulations, however, will totally "waterproof" concrete. That is, they will not prevent treated concrete from absorbing water and becoming saturated under conditions of complete and long-term submergence.

A frequent cause of concrete deterioration in dams and water conveyance structures is freezing and thawing damage. This is primarily a problem with concrete placed prior to the advent of air-entraining admixtures, which were discovered in the 1940s. These admixtures entrain very small air bubbles in concrete and, if properly distributed in the concrete, protect it in freezing weather. Three factors must be present for freezing and thawing damage to occur:

(1) Cycles of freezing and thawing temperatures
(2) Concrete that is more than about 90 percent saturated with water
(3) A concrete that is susceptible to damage (no or improperly entrained air voids)

When all three factors are present, water that has entered pores in the concrete freezes and expands about 10 percent as it becomes ice. The expansion causes cracks and forces the concrete apart. During thawing, more water enters and fills the enlarged voids. In the next freezing cycle, the concrete is further damaged by water expanding into ice (figure 2). The resulting damage can range from shallow surface scaling to entire sections of concrete crumbling into rubble.

Freezing and thawing damage can be prevented by eliminating one of the three factors. The most common approach is to reduce the available water by changing operating procedures, by improving drainage, or by using sealers or water repellents on the concrete. During repairs, a more resistant concrete can be used (dense concrete with proper air entrainment). The third option, that is often overlooked, is to reduce the number of cycles of freezing and thawing. This can be done by insulating the concrete or by changing operating procedures to keep critical areas under water (that does not freeze) in cold weather. Varying the depth of water over the years can also avoid concentrating the damage at one elevation.

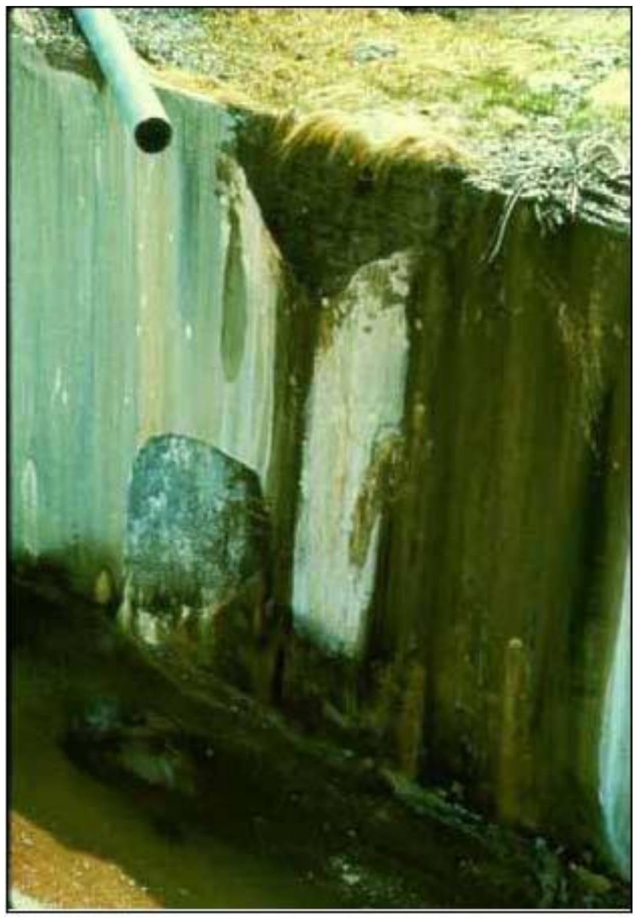


Figure 2.—Freezing and thawing damage resulting from continuous moisture exposure.

Another form of concrete maintenance is to prevent structural overloading. Operate gates in the right sequence. Do not exceed bridge load limits. Prevent damage from machinery. Do not drive equipment on slabs designed for pedestrian traffic.

Concrete in contact with high-velocity flowing water has special maintenance needs (figure 3). Small offsets at joints or small holes in the concrete surface can result in cavitation damage to concrete. The hole or offset causes the flowing water to separate from the concrete surface. This separation causes “bubbles” of negative pressure to form in the flowing water. When these vacuum voids collapse downstream, they exert forces that destroy concrete and most other rigid materials, including high-strength stainless steel.

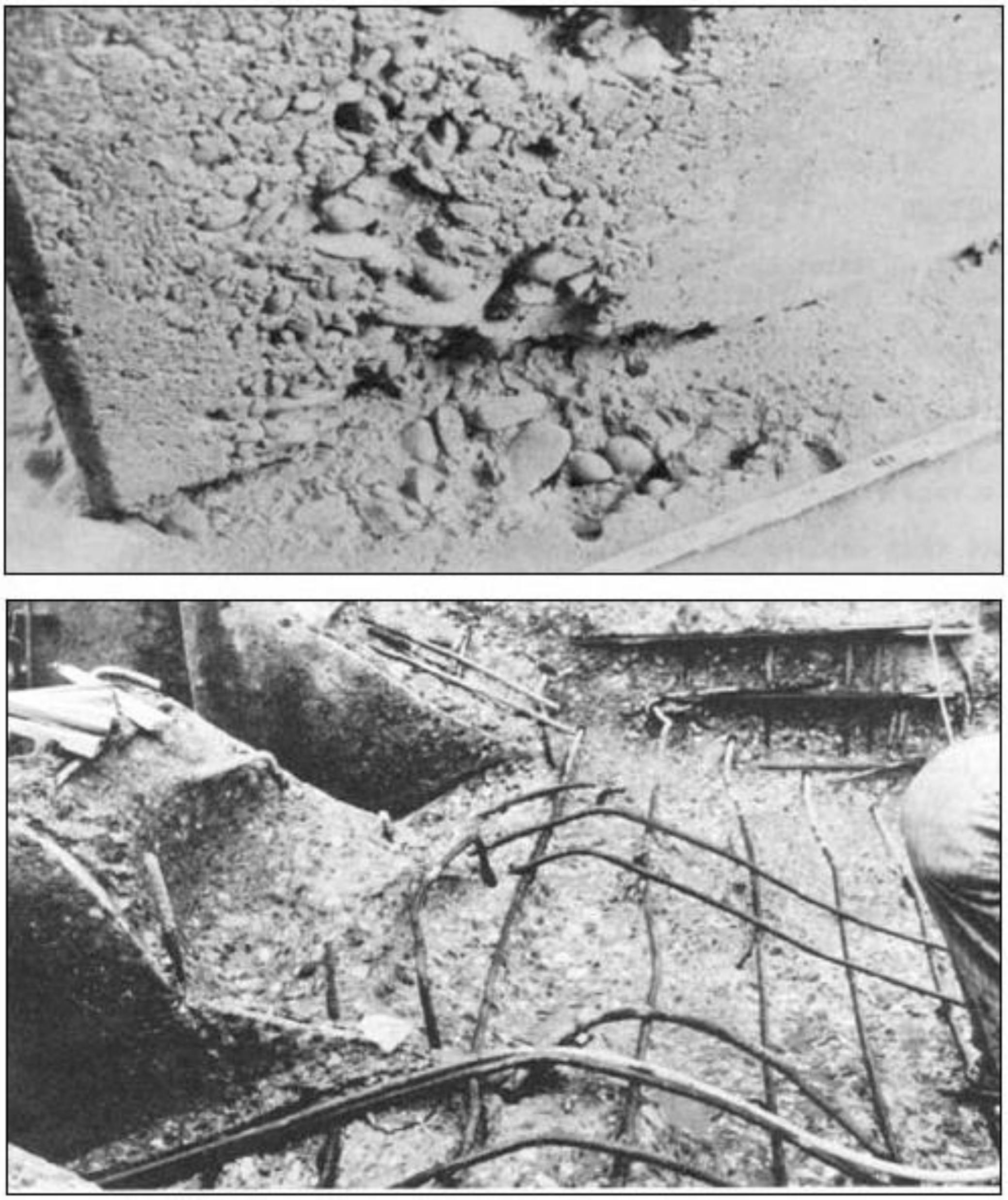


Figure 3.—Two types of concrete damage caused by waterflow: cavitation damage in upper photograph and abrasion damage from action of cobbles, etc., in water in lower photograph. Yellowtail Afterbay Dam, Montana. Photos C-8272-3NA and C-8272-23.

The newly damaged area causes more separation of flowing water, and cavitation damage will occur downstream from the most recently damaged area. This results in a series of damaged areas, each getting larger, downstream from the original offset. Proper concrete maintenance in high-velocity waterflow structures includes eliminating offsets and holes and repairing observed cavitation damage before it can enlarge to destroy the entire structure. Since no material will stand up to cavitation for a long time, the long-term solution is to manage the flow to avoid flows that will cause cavitation.

Another area of concrete maintenance is preventing abrasion damage. Flowing water, even at velocities too low for cavitation damage, can destroy concrete structures by the impact and grinding action of sand and rock carried in the water. Proper maintenance means reducing the amount of sand and rock in flowing water. Screens or settling areas at inlet structures can help. Retaining walls to protect flowing water from rock slides and fences to keep people from throwing rocks into the water are sometimes needed. Removing material from stilling basins should be a part of routine maintenance.

Concrete Repair

In spite of good maintenance, there will always be some structures requiring concrete repair. There are three choices when deciding on a repair. A permanent repair to attempt to return the structure to its original condition and function is a common approach. In some cases, however, a temporary repair is justified by its lower cost. Temporary repairs are used when a structure will soon be replaced, but must serve a few more seasons, or when funding is not available for a permanent repair. The third option of deciding to make no repair is often overlooked. Not all concrete with visible damage needs to be repaired. A spillway floor that has lost a fraction of an inch of concrete due to abrasion over the last 30 years will likely serve another 30 years without repair. In this case, the original concrete is of good quality and will likely serve better than any attempted thin repair material.

Cause of Damage

Before selecting a specific repair method, the cause and extent of concrete damage should be determined. Knowing what caused the damage and reducing or eliminating that cause will make the repair last longer. If no attempt is made to eliminate the original cause of damage, the repair will likely fail as the original concrete did. Freezing and thawing damage, structural overloading, cavitation damage, and abrasion damage have been discussed above. Sulfate-bearing waters or soils and alkali-aggregate reaction can also attack concrete. Design and construction defects can result in concrete damage due to improperly shaped flow areas, foundation settlement, weak concrete, poor finishing, structural overloading, poor curing, and other causes. Some concrete simply suffers from old age. All construction materials deteriorate eventually. Good design, construction, and maintenance will lengthen service life. Good concrete can last hundreds or thousands of years. Some Roman concrete structures, including the Pantheon and some aqueducts, are still functional after 2,000 years.

Causes of concrete deterioration and failure can be grouped into three general categories:

(1) Planning, design, or construction deficiencies. – These causes of failure could be due to inadequate foundation explorations, structural shortcomings due to improper design, omissions in operating criteria, inadequate construction supervision resulting in poor quality materials, etc. Also, improper selection of construction materials can result in alkali-aggregate reactions, chemical attack from sulfates in soil or ground water, freeze-thaw damage, and structural failures.

(2) Unforeseen conditions. – Such unexpected conditions as floods, storms, earth and rock slides, lightning, etc., can cause minor to severe damage to concrete structures.

(3) Natural attrition and old age. – All materials of construction are subject to aging and, concurrently, weathering and deterioration. The severity of the weathering process will depend upon the climatic conditions to which a structure is subjected as well as the type and quality of the original materials of which it was constructed.

Extent of Damage

Knowing the extent of damage is also necessary when planning a concrete repair. A shallow surface repair will not be effective if the damage extends deep into the concrete. Knowing the extent of damage will also help in confirming and mitigating the cause. Removing cores from the concrete is an excellent method of determining the extent of damage. Visual examination, petrographic examination (figure 4), and mechanical testing of concrete cores can give reliable information on the cause and extent of damage. Coring and testing are expensive and sometimes not justified for small repair jobs. Simple methods such as the rebound hammer, geologist pick, steel rod, and chain drag can frequently be effective in locating weak and delaminated areas of concrete. When major concrete repairs on significant structures are planned, high technology non-destructive methods such as acoustic testing and radar are sometimes used in condition assessment.

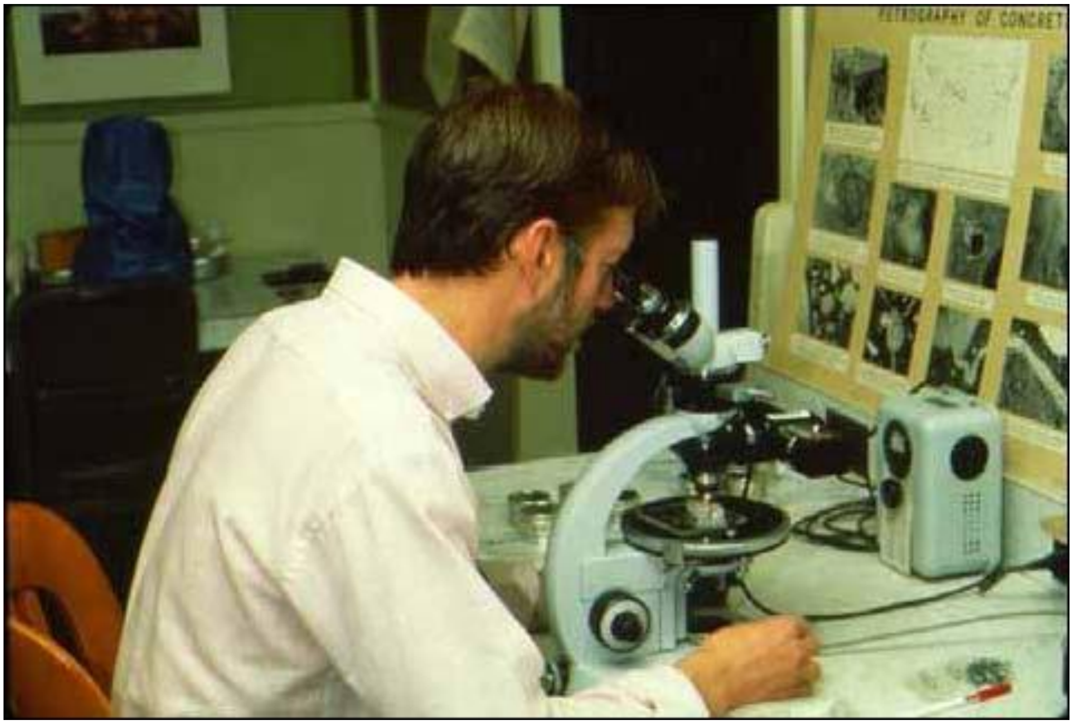


Figure 4.—Petrographic exam of concrete to help determine cause and extent of damage.

Concrete Removal and Surface Preparations

Proper preparation of the surface of the existing concrete is one of the most important steps to making a good, serviceable repair. Since the bond of the new material to the existing concrete is just as critical to the success of the repair as is the quality of the new material, great care must go into this phase of the repair operation.

All defective or damaged concrete must be removed. No repair is better than the poorest material involved, particularly that material adjacent to the new-old material interface. If in doubt as to the actual condition of the existing concrete, remove another inch of material, especially in the case of sulfate or freezing deterioration. It is good practice to continue removing concrete until aggregate is being broken rather than loosened in the matrix.

In addition to the removal of defective concrete, surface preparation for new material is very important. The surfaces must be clean, rough, and in a moisture condition suitable for the repair material when it is applied, whether it is concrete, epoxy, or whatever. After the defective material has been removed, the surfaces must be prepared by wet sandblasting, water blasting with approved equipment, or any other acceptable method, and then cleaned. The surface moisture should be brought to a condition suitable for the repair material being used. Different types of materials will have different surface moisture requirements. In the process of preparing the surfaces, care must be taken to prevent undercutting of aggregate in the existing concrete. It is advisable in the case of very old structures to wait several days after completing the surface preparation before applying the new material. Sometimes, concrete in old structures seems sound when cleaned, but will slake and soften after a few days' exposure. Care must be exercised to see that the cleaned and prepared concrete surfaces are maintained in that condition until repairs are made. Water seeps may be stopped by lead wool caulking or by cover drains. These may lead to sumps, to permanent weep holes, or to a vacuum system. Chemical grouting can also be used successfully, especially where leaks are from very fine cracks that are difficult to follow accurately with a routing tool, or in coarse, porous areas that are seeping. Any method of sealing that can be accomplished without contaminating the adjacent area is suitable for this work.

Repair Methods

Some basic concrete repair methods are discussed below. For a more extensive list of options and more technical details of repair, consult the most current edition of *Standard Specifications for Repair of Concrete*, M-47, Reclamation. Also, the *Guide to Concrete Repair*, published in 1996 by Reclamation, contains good information about maintenance and repair of concrete.

Concrete replacement—replacing a portion of the concrete in a structure without the use of a bonding agent—is one of the most effective concrete repair methods. It is used for large areas that are over 6 inches deep. Repairs of this size and depth usually retain moist curing conditions at the interface between new and old concrete for many weeks and, thus, develop a good bond. When concrete damage is less that 6 inches deep, it is sometimes still economical to excavate to a depth of 6 inches or more and use the concrete replacement method rather than using thinner repair methods that can be more difficult, more expensive, and less durable.

Dry pack is effective for small, deep repairs with nearly vertical edges such as core holes, form bolt holes, and slots. Dry pack is a mixture of cement, fine sand, and very little water. It is rich in cement, but has little shrinkage because of the low water content. After the hole has been prepared, the dry pack material is pounded into place in thin layers with a wooden rod to assure complete compaction. Continuous moist curing for at least 14 days is required to assure that the little water used in the dry pack is not lost and is available for cement hydration.

Mortar replacement is used in areas too wide for dry pack and too shallow for concrete replacement. It is simply Portland cement mortar placed either by hand or pneumatically with shotcrete equipment. This repair works best on new, green concrete (less than 24 hours old) that is still actively hydrating—thus, assuring good bonding between the repair and the base concrete.

There are cases when it is feasible to repair deteriorated or damaged concrete by plastering with mortar. This can be done by hand; but more often than not, it is done pneumatically and is called shotcrete. Considerable skill is required by the operators to assure a quality repair since they have control of the amount of moisture in the placement and the application. It can be difficult to get a pleasing finish using shotcrete; however, a satisfactory finish may be obtained by lightly rubbing the surface with a soft rag or burlap immediately after application.

Epoxy bonded concrete is used for repairs between 1½ inches and 6 inches in depth. It is essentially like the concrete replacement method, but because of the shallow depth, an epoxy bonding agent meeting ASTM C-881 requirements is used to assure good bond to the old concrete.

Epoxy bonded epoxy mortar is used for repairs less than 1½ inches in depth. Epoxy is used both as the bonding agent and as the cementing agent in the mortar. Epoxy mortar contains epoxy and sand. It contains no Portland cement and no water. While epoxy mortar is a strong, durable material, it sometimes disbonds from the substrate concrete when exposed to large temperature changes because its rate of thermal expansion is much different from that for concrete. Thus, if epoxy bonded epoxy mortar is used in an outdoor environment, it will likely become unbonded sometime in the future. Epoxy mortar repairs covering large areas on concrete slabs on grade sometimes trap rising moisture under the repair and then fail when the moisture freezes and expands. Epoxy bonded epoxy mortar repairs should not be used where there will be large temperature changes or where moisture can be trapped under the repair and subjected to freezing.

Silica fume concrete is the repair material of choice for applications requiring enhanced abrasion-erosion resistance and/or reduced permeability. Silica fume concrete is conventional Portland cement concrete containing admixtures of silica fume. Silica fume is a finely divided powder byproduct resulting from the use of electric arc furnaces. When mixed with Portland cement concrete, silica fume acts as a “super pozzolan.” Concrete containing 5-to 15-percent silica fume by mass of cement commonly can develop 10,000-to 15,000-pound-per-square-inch compressive strengths, reduced tendency to segregate, very low permeabilities, and enhanced freeze-thaw and abrasion-erosion resistance. Placing, finishing, and curing silica fume concrete is somewhat different than conventional concrete and should not be used until those differences are planned for. Otherwise, this repair material is used according to the provisions for conventional replacement concrete.

The above repair techniques give basic repair options for concrete based on the dimensions of the repair area. There are numerous other materials currently used in concrete repair including polymer concrete, silica fume concrete, and many versions of modified Portland cement concretes. The basic repair principles remain the same. Thicker and more massive repairs reduce the need for bonding agents and increase the chances of a durable repair. Thin repairs need bonding agents, but still have more chance of failure.

Repairing cracks in concrete requires different techniques. Narrow cracks can be repaired by filling with epoxy if the cracks are relatively dry and not moving. With proper technique, the structural integrity of the concrete can be restored. The crack is temporarily sealed along the concrete surface, leaving gaps for injections points and for air to exit. An epoxy material meeting requirements of ASTM C-881 is used for the structural repair. On large jobs, two pumps are used, one for each part of the two-part epoxy. The epoxy components are pumped through separate hoses to a mixing head where they mix and exit a single tube. The tube is connected to injection ports installed along the crack. When the crack is completely filled and the epoxy cures, the concrete sections are structurally bonded. On smaller jobs, simpler injection methods can be used such as pressure pots, caulking guns, or squeeze bottles.

It is sometimes necessary to repair concrete cracks without bonding structurally. In tunnels or pipes, cracks are sometimes sealed against water leakage while still allowing for movement due to loading and temperature changes. In recent years, polyurethane materials have been used to inject such cracks (figure 5). These materials will seal the crack, but they are soft enough to allow significant movements without causing leaks. Injection techniques for polyurethanes differ from those for epoxies, and such work is usually best performed by an experienced specialty contractor.

Figure 5.—Injecting a hydrophilic polyurethane resin to seal leaking joints in a pipeline.

Conclusions

Every facet or phase of concrete repair is important and critical to the success of the final product. Workmanship, material selection and treatment, and maintenance are all areas that, if properly considered, will ensure that a serviceable, long-life repair has been made. Large concrete repairs over 6 inches in depth, using Portland cement concrete and no bonding agent, are usually the most durable and, sometimes, the most economical. Thin repairs, while sometimes necessary, often use more expensive materials, more difficult techniques, and result in less durability. It is sometimes economical to overexcavate shallow areas of deterioration in order to make a deeper, longer-lasting repair. Conventional concrete should be the first choice for concrete repairs. Other materials should be used only where it can be shown that conventional concrete will fail. While good quality original construction concrete is usually superior to any repair, repairs of sufficient quality to greatly extend a structure's life can be made with the techniques discussed.

In conclusion, and to verify some of the statements made herein through the writings of an old water works operator, the following is quoted:

> *Requirements for Good Concrete – Repairs that can be carried on without cutting off the water of the aqueducts consist principally of masonry work, which should be executed at the right time, and conscientiously. The proper time for masonry work is from the first of April to the first of November; but with this restriction: That the work be interrupted during the hottest part of the summer; because moderate weather is necessary for the masonry properly to absorb the mortar and to solidify into one compact mass; for the heat of the sun is no less destructive to masonry than is too violent frost. Nor is greater care required upon any works than upon such as are to withstand the action of water; for this reason, all parts of the work need to be done exactly according to the rules of art, which all the workmen know, but few observe.*

Excerpted from the Water Supply of the City of Rome of Sextus Julius Frontinus, Water Commissioner of the City of Rome, A.D. 97

Visual Checklist for Canal Embankment and Repairs

As a result of conditions possibly threatening the structural integrity of a canal embankment (e.g., seepage, subsidence, displacement, etc.), periodic monitoring is often prudent and recommended. This is particularly important in order to identify the timing of additional actions to take to reduce/minimize the likelihood of failure and to begin and assist with the notification process related to emergency management activities. The following is an example of a visual inspection checklist that Reclamation and several of its water user operating entities have utilized in the recent past to monitor and document items of concern associated with canal embankments. The checklist can also be used to monitor canal embankment conditions, during the watering-up process of the canal, following repairs to a canal embankment.

The checklist can and should be revised to make it specific to local conditions and particular structures of concern. The frequency of monitoring and completing the checklist will also be dictated by the extent and progress of the particular conditions affecting the canal embankment.

Canal Name Date: ____________

Agency -

Schedule: 24-hour monitoring of the canal should be performed until normal operation flows are achieved.

Inspector: ____________ **Date:** ____________

Canal Elev.: ____________ Feet **Time:** ____________

Weather: ____________ **Temperature:** ____________ °F

A "YES" response should be given to question(s) below where observed conditions are different than previously observed conditions. Re-reporting conditions that have previously been reported and currently are unchanged should not be done ("NO" answer would be appropriate). For any question answered "YES", please promptly telephone the contact listed below (when appropriate), and please provide additional information describing the situation as completely as possible under item 7, "Additional Information." Also, take photographs of the situation, and include with this report, as appropriate.

FAX completed form to: ____________ **FAX:** ____________ **Phone:** ____________

1. Embankment- Inside Canal Prism:

a. Any significant erosion or beaching due to wave action? ❐ No ❐ Yes

b. Any sinkholes, sloughs, or areas of unusual settlement? ❐ No ❐ Yes

c. Any evidence of whirlpools in the canal? ❐ No ❐ Yes

2. Embankment Crest:

a. Any new cracks, either transverse or longitudinal, or significant changes at any existing cracks? ❐ No ❐ Yes

b. Any other sinkholes, depressions, or areas of unusual or excessive settlement? ❐ No ❐ Yes

3. Canal Embankment:

a. Any seepage areas or wet areas? ❐ No ❐ Yes

b. Any evidence of materials being transported by seepage flows (such as discolored water or sediment deposits)? ❐ No ❐ Yes

c. Any other sinkholes, depressions, sloughs, slides, or areas of unusual settlements or deformations? ❐ No ❐ Yes

d. Any bulging evident, particularly near the toe of the slope? ❐ No ❐ Yes

e. Any evidence of damage, uneven flow surfaces, etc. ❐ No ❐ Yes

4. Downstream Toe Area, Abutment Areas, and Areas Downstream of the Canal Embankment:

NOTE: Extend the inspection to all areas within 20 feet of the downstream embankment toe. Carefully observe the existing seepage/wet areas: (1) between the check structure and the canal embankment, (2) at canal embankments. Also, carefully observe the area around the check structures and laterals for evidence of new seepage/wet areas.

a.	Any new seepage areas or wet areas?	❐ No	❐ Yes
b.	Any significant changes in conditions at the seepage/wet area between the canal features and embankment?	❐ No	❐ Yes
c.	Any significant changes in conditions at the seepage/wet area at the embankment?	❐ No	❐ Yes
d.	Any significant changes in conditions at the seepage/wet area at the intersection between the main canal and laterals?	❐ No	❐ Yes
e.	Any evidence of materials being transported by seepage flows, new or existing (such as discolored water or sediment deposits along flow paths)?	❐ No	❐ Yes
f.	Any slides, sloughs, sinkholes, depressions, or areas of unusual settlement?	❐ No	❐ Yes
g.	Any evidence of damage, undermining erosion, etc.	❐ No	❐ Yes

5. Laterals (upstream and downstream ends):

a.	Any new cracks, or other cracks that have enlarged, or spalls in concrete?	❐ No	❐ Yes
b.	Any debris clogging the drop inlet?	❐ No	❐ Yes
c.	Any erosion evident downstream of the discharge structure?	❐ No	❐ Yes
d.	Any significant seepage flow occurring through the conduit?	❐ No	❐ Yes
e.	Any seepage flow occurring immediately adjacent to the conduit?	❐ No	❐ Yes
f.	Any evidence of materials being transported by seepage flows (such as discolored water or sediment deposits)?	❐ No	❐ Yes
g.	Any unusual flow patterns during periods of discharge (such as rooster tails, turbulence at joint offsets, etc.)?	❐ No	❐ Yes

6. Check structure:

a.	Any cuts, scars, damage etc. in the flow channel that might lead to significant erosion and downcutting during times of significant flow through the check structure?	❐ No	❐ Yes
b.	Any unusual flow patterns during periods of discharge (such as rooster tails, turbulence, hydraulic jumps in unusual locations, etc.)?	❐ No	❐ Yes
c.	Any evidence of significant erosion by flood flows that could undermine the check structure	❐ No	❐ Yes

7. Additional Information:

Provide additional information concerning any of the above questions that were answered "YES:"

NOTE: All descriptions should include specific location information and all other seemingly relevant information. Seepage area descriptions should include estimated seepage amount and water clarity description (clear/cloudy/muddy, etc.). Crack descriptions should include orientation and dimensions. Descriptions of changes at joints should include the estimated amount of movement, and movement direction. Deteriorated or spalled concrete descriptions should include degree of deterioration and approximate dimensions of the affected area.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

Darrel Krause, Bureau of Reclamation, ATTN: 84-57000, PO Box 25007, Denver, CO 80225-0007; (303) 445-2941; email: DKrause@usbr.gov

Kenneth Schwairy, Bureau of Reclamation, ATTN: 86-68360, PO Box 25007, Denver, CO 80225-0007; (303) 445-3015; email: KSchwairy@usbr.gov

James Dean, Pacific Northwest Region, ATTN: PN-3200, 1150 North Curtis Road, Boise, ID 83706-1234; (208) 378-5398; email: JDean@usbr.gov

Paul Caruso, Mid-Pacific Region, ATTN: MP-4300, 2800 Cottage Way, Sacramento, CA 95825-1898; (916) 978-5224; email: PCaruso@usbr.gov

Scott Foster, Lower Colorado Region, ATTN: LC-6600, PO Box 61470, Boulder City, NV 89006-1470; (702) 293-8144; email: SFoster@usbr.gov

Rick Scott, Upper Colorado Region, ATTN: UC-1000, PO Box 11568, Salt Lake City, UT 84147-0568; (801) 524-3726; email: RScott@usbr.gov

Dave Nelson, Great Plains Region, ATTN: GP-2400, PO Box 36900, Billings, MT 59107-6900; (406) 247-7630; email: DENelson@usbr.gov