NATIONAL TRANSPORT RESEARCH CENTRE

BRIDGE INSPECTION MANUAL

M. A. FAROUK
Deputy Chief

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Executive Summary

Bridges and culverts are built as permanent structures on a road. As far as maintenance is concerned, there is no such thing as a permanent structure. Deterioration of bridges and culverts begins as soon as they are constructed, as a result of weather conditions, traffic wear, or other normal operating conditions. Without normal maintenance, the service lives of bridges and culverts would be seriously shortened. Repairs and restorations are required against gradual deterioration, damage by storms, floods and accidents.

Bridges must be very well maintained in order to keep the roads open to traffic. Culverts too are important as they are like small bridges, more numerous on the road than bridges and if a culvert collapses the road may have to be closed.

Maintenance operations on bridges consist primarily of painting, cleaning bridge seats, repairing and sealing joints, strengthening and replacing damaged bridge members, and inspecting foundations for dangerous scour conditions and taking the necessary steps to prevent damaging undercutting of piers and abutments. Repairs are undertaken to replace the worn out bridge decks and provide any other services necessary to preserve the structural integrity of the bridge. Culverts have to be kept clean from debris and vegetation. Any scour at ends of culverts or at edge of culvert apron is to be repaired and poor concrete replaced.

Bridge maintenance is generally overlooked, considering these to be permanent structures. Appearance of a hole by falling off a chunk of concrete from an old bridge deck or a similar incident brings the

importance of regular bridge maintenance into focus. At present there are no formal inspection procedures prevalent in our highway departments. The basic objective of the compilation of this Manual is to introduce formal inspection on a standardised format to be adopted by all the highway agencies. Inspection is a pre-requisite to proper maintenance.

This Manual has been compiled in three parts. Part I deals with description of Bridges and Culverts and their components with diagrams. Part II contains procedures and methods of proper maintenance and repairs so that the structures are maintained in a fully serviceable condition. Part III pertains to inspection. Fundamental to bridge maintenance is bridge inspection which must be undertaken periodically by a competent bridge engineer and accepted by his superior. The maintenance and repairs as revealed by the inspection report must be undertaken by skilled workmen under close

supervision so that the repairs are sound and prolong life of the structure. The inspection forms cover all type of Bridges and Culverts, constructed of wood, masonry, concrete or steel. In the end an Appendix has been added which lists Typical bridges in Timber, masonry, steel and concrete materials. Sketches of arch, cantilever, suspension, swing, foot and pontoon type of bridges have been included to familiarize the reader with various type of bridges in use.

It is hoped that the field engineers would find this manual handy and helpful in carrying out bridge and culvert inspection and undertaking sound repairs to enhance life of these structures.

PART I

BRIDGES AND CULVERTS

PART I. BRIDGES AND CULVERTS

INTRODUCTION

Bridges can be the weak links in a road network by virtue of their load carrying capacity or state of maintenance and repair. They must be kept well maintained in order to keep the roads open to traffic. Culverts are very important too, because they are like small bridges and if a culvert collapses, the road may have to be closed.

Highway bridges are designed to resist loads produced by the weight of the structure (dead load), the weight and dynamic effect of moving loads (live load and impact), and wind loads. Structures on curves must resist centrifugal forces developed by moving vehicles. Under certain circumstances, stresses resulting from temperature change, earth pressure, buoyancy, shrinkage, rib shortening, erection, ice and current pressure, and earthquakes are also considered.

In the simplest terms, bridges consist of substructures of abutments and piers which support superstructures that carry the roadway between these supports. Types include, among others, slab, girder, truss, arch, and suspension bridges, each with a distinctive form of superstructure. Rigid or continuous frame structures are bridges in which the substructure and superstructure are rigidly joined. A further distinction is made in terms of materials, the most common of which are reinforced concrete, structural steel, and timber. Aluminum has also been used.

The suitability of the various bridge types is governed primarily by the length of individual spans. Short-span structures, ranging up to about 60 ft, are generally either (a) reinforced-concrete rigid frames with slab decks (similar in cross section to the bridge culverts shown in Fig. 15; (b) T beams or box girders of reinforced concrete; or (c) steel or prestressed concrete I beams with reinforced-concrete decks. Precasting and prestressing of the reinforced-concrete portions of these structures is now common practice. A combination of timber stringers with timber or reinforced-concrete deck is sometimes used for spans of less than about 20 ft. Bridges of somewhat longer spans are often (a) girder type rigid frames of reinforced concrete or steel; (b) T beams or box girders of reinforced concrete; or (c) steel plate girders with reinforced-concrete decks. When spans greatly exceed 300 ft, steel trusses or arches of steel or reinforced concrete are usually favored. Spans greatly in excess of 500 ft are generally steel trusses or suspension bridges. Where provision is made to pass ships through rather than under the roadway level, the channel span generally is selected from the vertical-lift, swing, or bascule types.

Bridge Components

The simplest bridge of a single span is shown in Figure 1. Its components are super structure, sub structure, abutments, bearings, joints, parapets, approach embankments, retaining walls, approach roads, wingwalls, retaining walls, bearing shelf, Ballast wall and piers. Each of the component is described with figures here in after.

Abutment

The super structure sits on abutments as shown in Fig. 1.

Parapet

It is along the both edges of the super structure and prevents passer by and light vehicles falling off the bridge (Fig. 1).

Approach Embankments

The abutments also retain the approach embankments (Fig. 1).

Retaining Walls

Retaining walls next to abutments holds back the approach embankments (Fig. 1).

Approach Road

The approach road runs along the top of the approach embankment on to the bridge (Fig. 1).

Super Structure

Super structure is part of the bridge which carries the road. Various types of super structures are shown in Figure 2(i to viii).

Piers

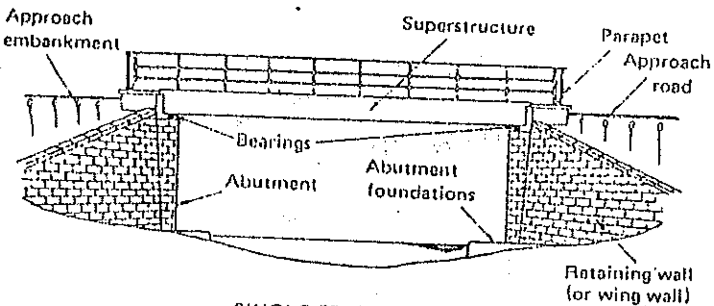
The intermediate supports between the two ends of the bridge are called piers (Fig.3). Abutments and piers are called sub structure of a bridge. Piers have spread, pile or caisson foundations as shown in Fig. 4(i to iii).

Masonry Arch Bridges

Masonry arch bridges are made from brick or stone masonry. The arch barrel (Fig. 5) is supported on foundations. The fill which carries the roadway over the arch is contained by spandrel walls (Fig. 5). The spandrel walls usually continue above the roadway as parapets.

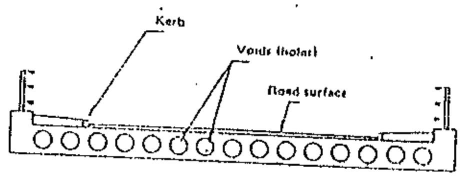
Abutment Foundations

The weight of super structure and abutments is carried by the abutment foundations. Abutments have spread, pile or caisson foundations (Fig.6).



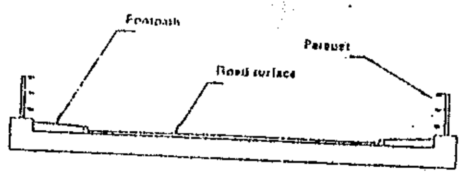
SINGLE SPAN BRIDGE

Fig.1



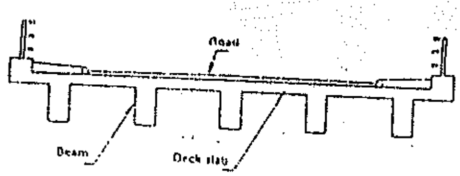
CONCRETE SLAB (VOIDED)

Fig.2(i)



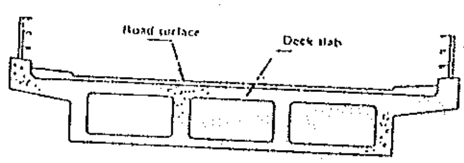
CONCRETE SLAB (SOLID)

Fig.2(ii)



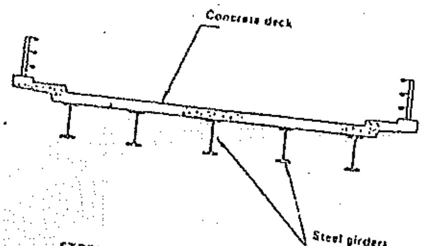
CONCRETE BEAM AND SLAB

Fig.2(iii)



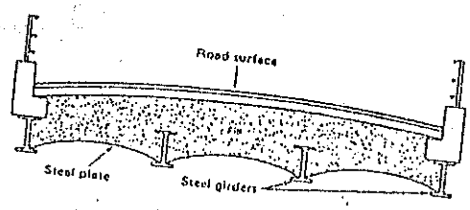
CONCRETE BOX GIRDER

Fig.2(iv)



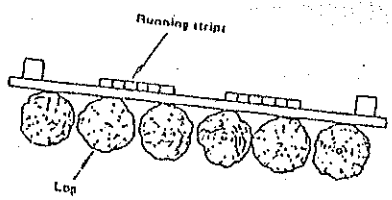
STEEL GIRDERS WITH CONCRETE DECK

Fig.2(v)



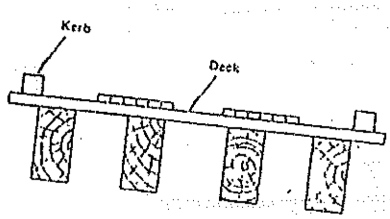
STEEL GIRDERS WITH JACK ARCH DECK

Fi .2(vi)



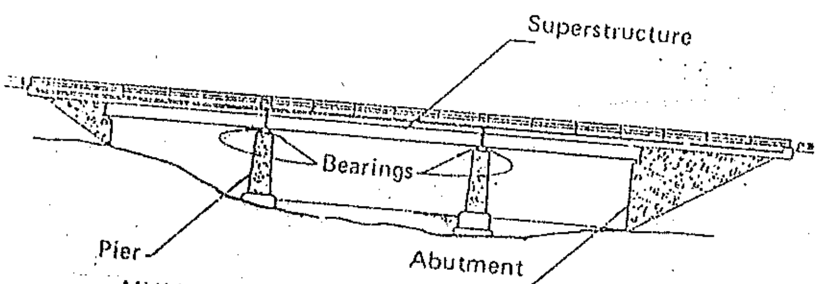
LOG BRIDGE

Fig.2(vii)



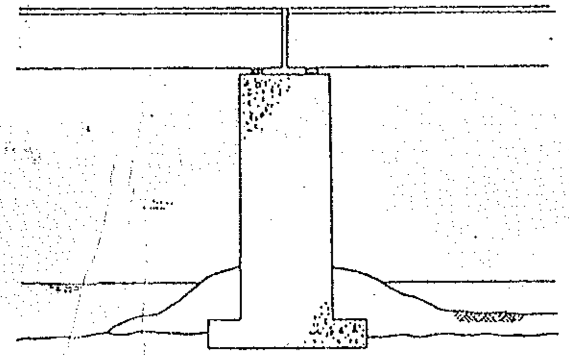
TIMBER BEAM

Fig.2(viii)



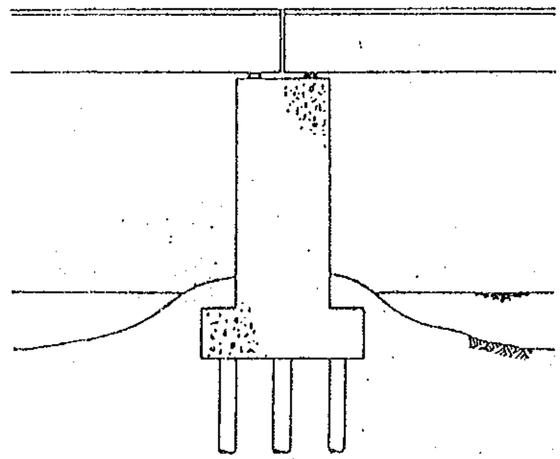
MULTI– SPAN SIMPLY SUPPORTED BRIDGE

Fig.3



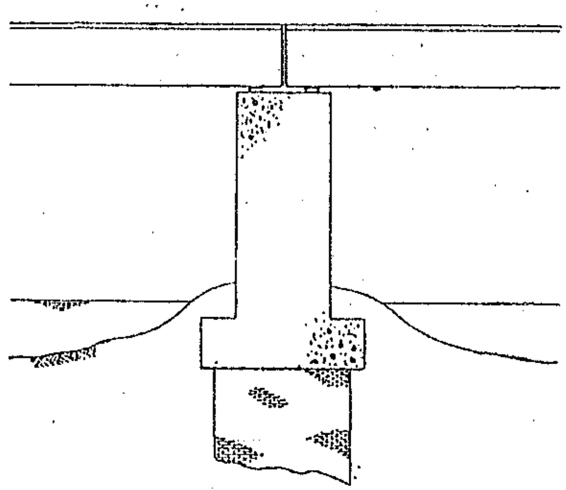
CONCRETE PIER ON SPREAD FOUNDATION

Fig. 4(i)



CONCRETE PIER ON PILES

Fig. 4(ii)



CONCRETE PIER ON CAISSON

Fig. 4(iii)

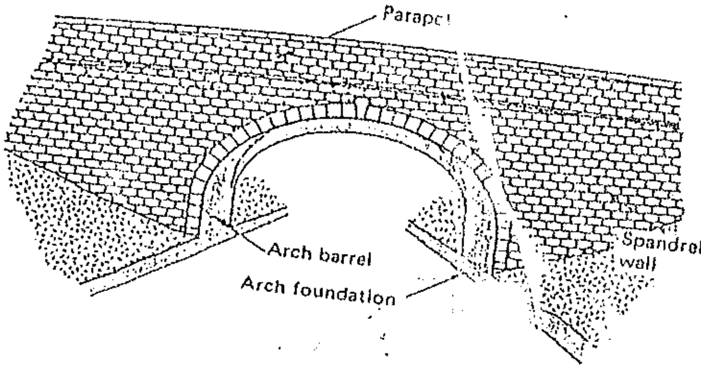

Parapet
Arch barrel
Arch foundation
Spandrel wall

Fig.5

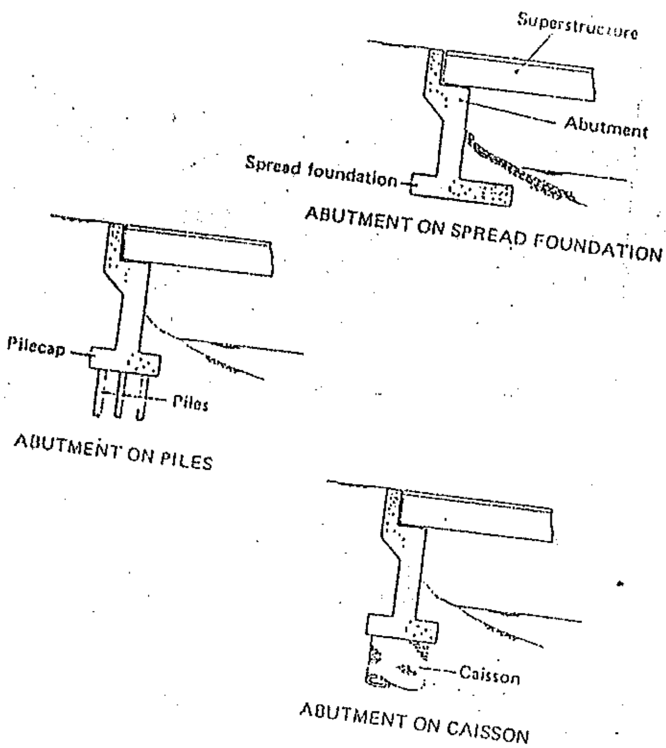

Superstructure
Abutment
Spread foundation
ABUTMENT ON SPREAD FOUNDATION
Pilecap
Piles
ABUTMENT ON PILES
Caisson
ABUTMENT ON CAISSON

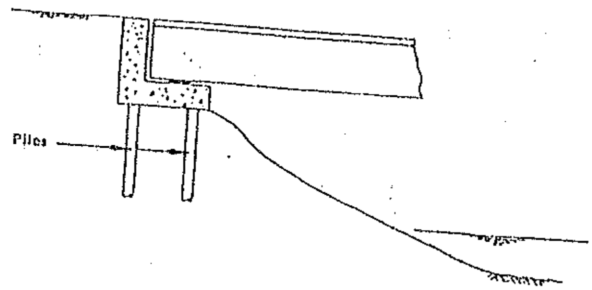
Fig.6

Bank Seat Abutments

Sometimes abutments sit high up on the river bank. These abutments are called Bank Seat abutments. These may have pile or spread foundations [Figs. 7 (i) to (ii)].

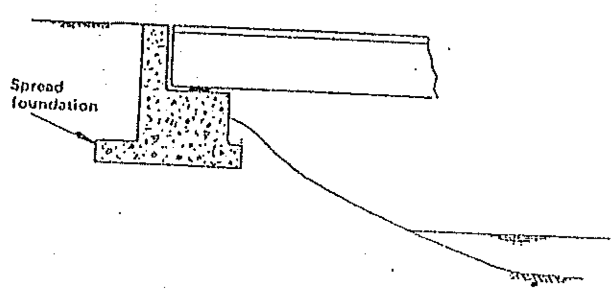
Bearing Shelf

The super structure rests on bearings on the abutment bearing shelf (Fig. 8).



BANK SEAT ABUTMENT ON PILES

Fig.7(i)



BANK SEAT ABUTMENT ON SPREAD FOUNDATION

Fig.7(ii)

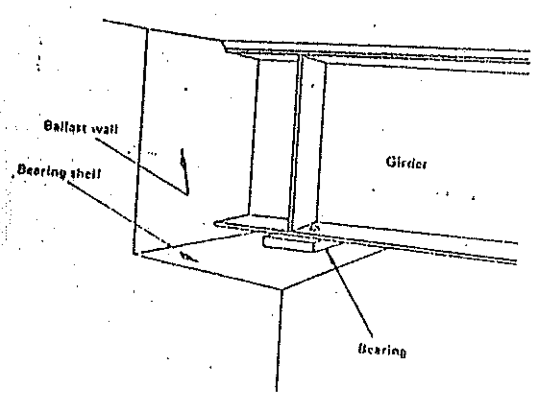


Fig.8

Movement due to temperature Variations

With temperature variations, the super structure changes its length [Fig. 9(i)]. One end of the span is fixed to the pier or abutment and the other end is free to move. In moderate climate, a bridge 50 meters long will change its length by about 25 mm (1 inch). In areas with big temperature differences, the change in length (expansion) will be bigger. If the super structure is fixed to both abutments, it will damage them when it changes length. On all major bridges, the super structure rests on bearings. The bearings carry the weight of the super structure and allow it to move a little [Fig. 9(ii)].

Bearings

If the super structure is free to move at both ends, it could fall off its bearings. To avoid this, one end is fixed to the abutment or pier and the other end is free to move. Fixed bearings have a pin or bolt fixing the beam to the support through the bearing. The bearing shown in Fig. 10 is a fixed type bearing, called a rocker bearing.

Ballast Wall

The part of abutment which holds back the approach embankment above the bearing shelf is called the ballast wall (Fig. 11).

Wing Wall

Wing walls are attached to the abutment. They retain the approach embankment. Fig. 11 shows an abutment with wing walls. Some times retaining walls are used to hold back the approach embankment. They are separate from the abutments and are shown in Fig. 12.

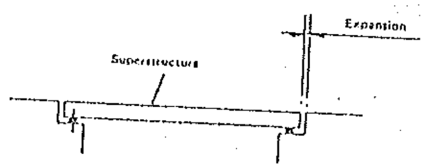


Fig.9(i)

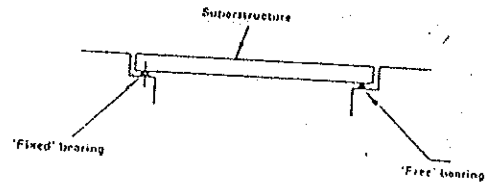


Fig.9(ii)

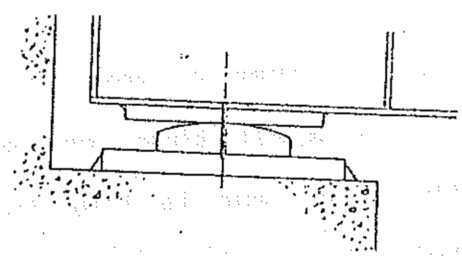


Fig.10

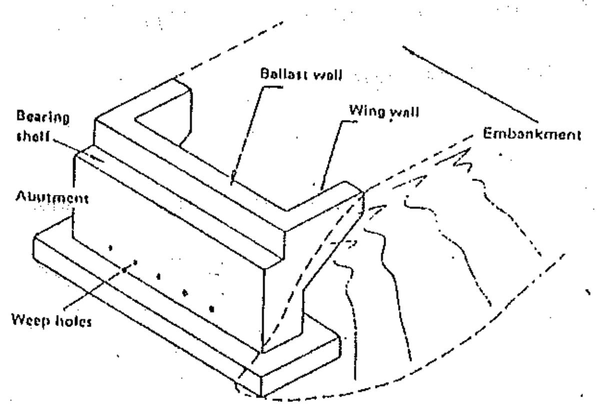


Fig.11

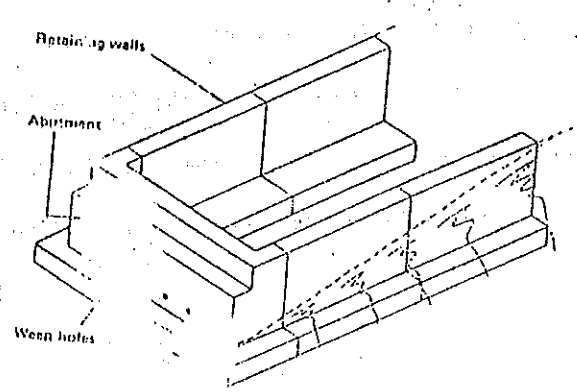


Fig.12

Joints

At the road surface, between the Deck and the ballast wall, there will be an expansion joints. There are many different types of expansion joints. The simplest joint is made by using the steel angles in the end of the deck, and in the top of the abutment ballast wall (Fig. 13). Some times a rubber water Bar is used to stop water and dirt from going through the expansion gap (Fig. 14).

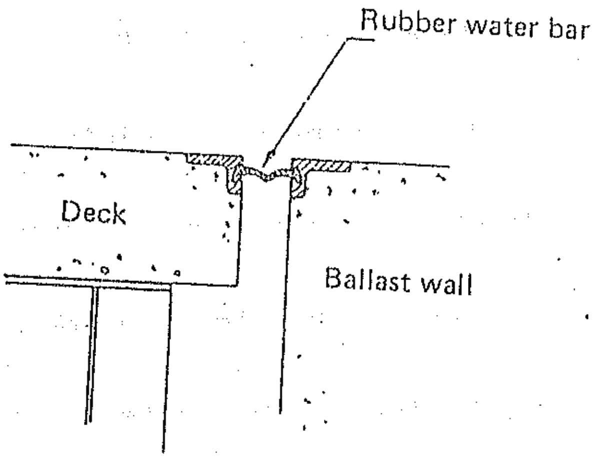

Rubber water bar
Deck
Ballast wall

Fig.13

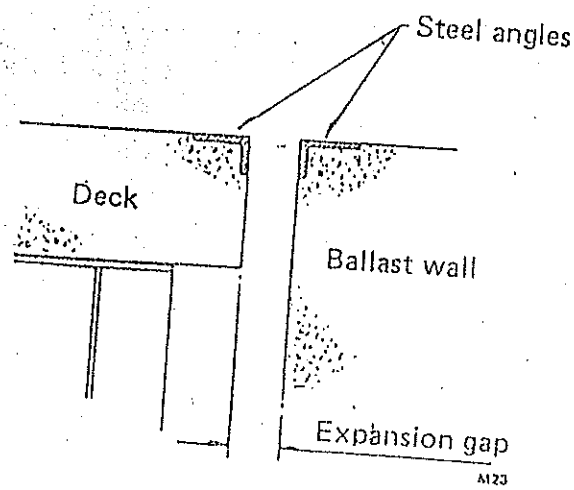

Steel angles
Deck
Ballast wall
Expansion gap

Fig.14

Culverts

The term "culvert" encompasses practically all closed conduits used for highway drainage with the exception of storm drains. Culverts might be classed as stock products, in that standard designs are used repeatedly. This in direct contrast to the situation for bridges that span larger streams, for which special designs are made in almost every case. Culverts are far more numerous than bridges, and more money is spent on them. In fact, about one-sixth of the highway construction expenditure goes for these smaller drainage structures.

The more common culvert types and the materials of which they are made are shown in figure 15. For smaller openings, pipe in stock sizes is generally chosen, with the pipe arch as a substitute where headroom is limited. For openings of moderate size, pipe and box culverts compete for favor. For larger openings, single or multiple span box culverts are generally used, although one or more large diameter pipes of reinforced concrete or bolted metal plates sometimes are preferred. Bridge culverts replace box culverts when the foundation is nonerodible and a paved floor is unnecessary. Arch culverts may be economical under high fills where loading is heavy.

Under normal circumstances, selections of culvert type and material are based on comparative costs. At times, however, other factors may control. For example, the presence of corrosive agents in the soil may bar

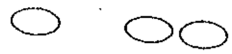
Culvert Type	Typical Cross Sections	Common Materials
Pipe, single or multiple Circular		Corrugated metal, plain or reinforced concrete, vitrified clay, cast iron.
Oval		Concrete
Pipe arch, single or multiple span		Corrugate metal, Precast reinforced concrete
Box culvert, single or multiple span		Reinforced concrete
Bridge culvert, single or multiple span		Reinforced concrete
Arch		Reinforced concrete, corrugated metal or stone masonry arch on reinforced concrete foundation

Figure 15. Common Culvert Types and Materials.

certain materials unless a means of protection can be devised. Again, if the structure location is remote, the portability and ease of erection of light, prefabricated metal sections may make them particularly desirable. At times, factors such as the availability of skilled labor or time limitations may govern. In any event, the decision must be based on careful study of all pertinent factors.

Accepted materials for corrugated metal culverts are galvanized copper bearing pure iron, copper-steel, and aluminum alloy. All have relatively high resistance to corrosion. This resistance of the special iron or steel is increased further by galvanizing the individual sheets before they are shaped. In forming the pipe, individual sheets (usually wide enough to provide it culvert lengths) are bent to the selected cross section. Joints are lapped and fastened either by welding or with cold-driven rivets of the base metal. During forming, circumferential corrugations are pressed into the metal. These vary with pipe diameter. For example, for iron and steel pipe with diameters 12-36 in, corrugations are 1/2 in deep on 2 2/3 in centers. For larger diameters up to 120 in. these dimensions may be, respectively, 1 in. and 3 in. individual sections are assembled at the shop into lengths convenient for transportation and field handling. Field connections between these lengths are made with corrugated metal bands pulled tight with galvanized bolts. Large diameter pipes, arches, and arch culverts of corrugated metal are made up into segments of manageable size that can be assembled and bolted into a unit on the site. Some times the specifications require that pipe sections be coated with bituminous material to provide added protection. For situations where the stream carries sand, gravel, or other abrasives, the invert may be paved with bituminous mastic.

Culvert pipe of plain or reinforced concrete, cast iron, or vitrified clay is made at the plant in standard lengths. Jointing between individual sections, using specified materials and methods, follows bedding of the pipe. Highway agencies have standard drawings covering culvert designs appropriate for the more common heights and widths of openings, fill heights, and skew angles. Culverts through embankments demand particular attention to protect them from damage by construction equipment and to secure proper soil compaction around them. Some agencies require that the embankment first be constructed above the level of the culvert crown, after which a trench is dug for the culvert.

Most culverts begin upstream with headwalls and terminate downstream with endwalls. Headwalls direct the flow into the culvert proper, while endwalls provide a transition from the culvert back to the regular channel. Both protect the embankment from washing by flood waters. Common types are diagrammed in figure 16. Most headwalls and endwalls are cast in place of reinforced concrete, although rubble masonry and timber have been used at times. Units prefabricated of corrugated metal or precast of concrete are sometimes installed with pipe of the same materials. In all cases, cutoff walls extending below the level of expected scour should be incorporated in the design. Often a paved apron extending beyond the cutoff wall is a wise addition.

Straight headwalls and endwalls are selected mainly with smaller pipe culverts [see figure (16-a)]. They are hydraulically inefficient as entrances. In recent years, some agencies have been omitting endwalls and, sometimes, headwalls from small pipe culverts. Instead, the pipe is extended beyond the toe of the embankment. From a hydraulic point of view this design is inefficient, since the entrance loss for a projecting thin-walled pipe flowing full is about 0.8 velocity head.

The L type headwalls [Figure (16-b)] direct the flow from roadside ditches into culverts under the road. They create a serious accident hazard, and many agencies are replacing them with gutter inlets covered with grates. For large culverts, wing type walls [figure (16-c)] are most widely used. Entrance losses with them are about 0.15 of a velocity head as contrasted with a loss of 0.05 with hydraulically designed entries (see below). Flared, U, and warped walls [figure 16(d-g)] have special applications.

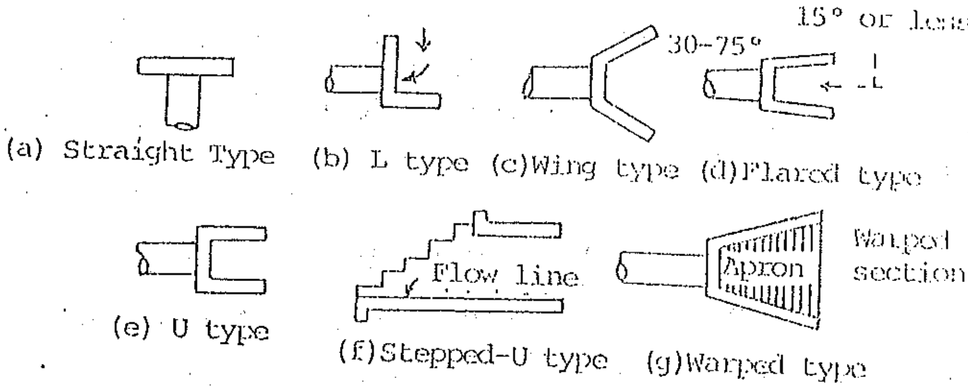


Figure 16. Typical headwalls and endwalls for culverts.

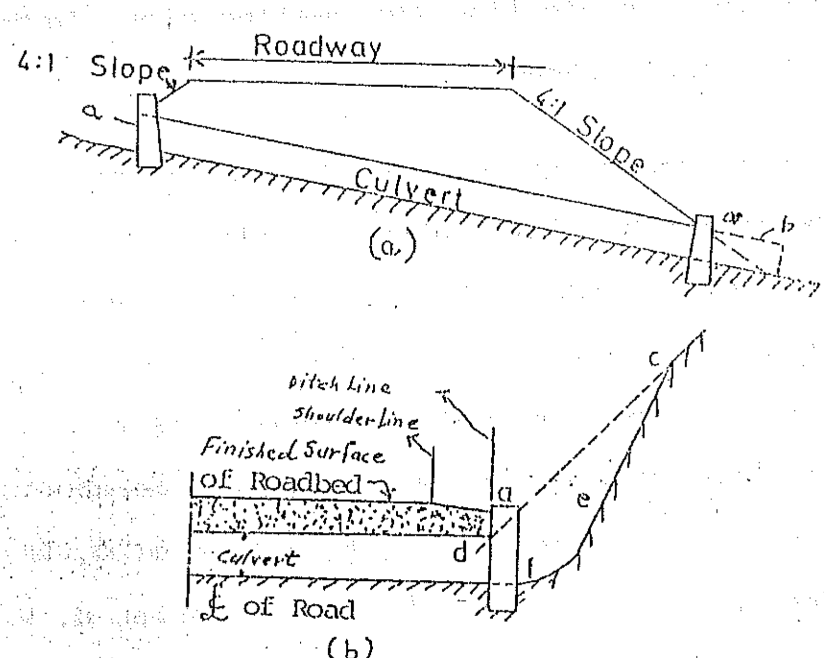


Fig.17. Proper Installation of Pipe Culverts (a) in Fill and (b) in Cut.

Culverts on steep slopes or carrying large flows often discharge at such high velocities that they create serious erosion problems in unprotected channels. Some velocity reduction can be gained by roughening the floor and walls of the culvert. Usually, however, the excess energy is dissipated at the discharge end of the culvert by creating a hydraulic jump if the flow is supercritical, or by generating turbulence in some other manner. One effective means is to direct the flow into a basin lined with rock, either of one size or graded from sand through large boulders. At times a downstream sill may be provided. Other devices have been developed which involve baffles and sills. The greater flow resistance offered by corrugated-metal pipe likewise can sometimes be used to advantage in reducing velocity through the culvert. Drops in the upstream channel or drop inlets to the culvert proper, if designed to produce free fall in the stream, sometimes offer an economical means for velocity control.

Streams in flood often carry brush and occasionally transport large branches, whole trees, or other sizable objects. There are many instances where this floating debris has clogged culvert entrances and raised the headwater elevation till the road was overtopped or adjacent property damaged by flooding. Where possible, culverts should be designed to pass expected debris. For example, where a stream may carry large floating objects, a single large-span box culvert is preferable to a multispan structure of the same total opening. As a possible alternative, the curtain wall separating the barrels of the multispan culvert might be extended upstream, with its top slanting downward. Debris will ride up on this wall, or at least be turned to pass more easily through the opening. In many cases, upstream debris racks of wire, timber, steel rails, piling, or other materials may offer the most reasonable solution to the problem. With such installations, maintenance crews must remove the debris following each flood.

At times, it may be desirable to trap sand or gravel carried by the stream rather than to pass it through the structure. Again, in mountainous areas, large rocks and boulders may be tumbled along the stream bed. Here also provision must be made either to pass this detritus through the structure or to trap it upstream where it will do no harm.

Design of debris-control devices depends on the form of debris or detritus to be handled, the volume of flood water, and individual site conditions. Experience in similar situations is a most useful guide.

Culverts usually are installed in the original stream bed with their grades and flow lines conforming to those of the natural channel. In this way, disturbance to stream flow and the erosion problems it creates are held to a minimum. In rolling and mountainous country in particular, marked departures from channel alignment either upstream or downstream may direcdt the current to one side of the channel, causing erosion there and deposition on the opposite side. On the other hand, culverts on substantial skews are longer and more costly than those at right angles or on small skews. Often the best solution involves reducing large skews somewhat and providing a channel change and erosion protection at one or both ends of the structure.

In rough country, culverts can sometimes be advantageously located on a bench on the side of the canyon rather than in the channel. Under high fills, positioning in the channel is costly as culverts must be very long and carry heavy loads. Use of the side hill location reduces both length and load. On the other hand, the erosion threat at the outlet may require expensive control measures. Also, objections to ponded water because of health or safety hazards and threats to stability of the fill must be overcome. Where the stream bed is steep, a compromise solution with the culvert entrance lowered to the stream bed level and the culvert on the sidehill may be most satisfactory. Curvature or breaks of grade to make the culvert conform to the channel should be used if the design is cheaper and is hydraulically and structurally sound.

Inverted siphons should be avoided whenever the water carries sediment or debris. Even though the velocity at peak flow may keep the barrel clear, deposits may collect as the discharge decreases. Also, stagnant water trapped in the sag may be objectionable.

PART II

MAINTENANCE AND REPAIR

PART II. MAINTENANCE AND REPAIR

General:- There is no such thing as a permanent structure. Deterioration of bridges and culverts begins as soon as they are constructed, as a result of weather conditions, traffic wear, or other normal operating conditions. The same services for which the highway was built require that it be maintained in a fully serviceable condition. Without normal maintenance, the service lives of the pavements and roadway structures would be seriously shortened. Present transportation needs for highways require that maintenance operations provide for year-round use 24 hours a day. Transportation services must be maintained for the health and welfare of the public as well as for the normal needs of commerce.

Gradual deterioration, damage by storms, floods, and sudden failures due to weather and other conditions, and obstructions occurring as a result of storms, floods, cause traffic accidents and delay to the commerce of the nation. Repairs must be made and damage must be prevented if the highway is to serve the purpose for which it was constructed and for which large sums of money were spent.

Federal, provincial and local governments appropriate large sums for road maintenance annually. Some of this money is spent upon minor improvements made by the

Highway departments, but most of it is expended on normal maintenance.

Maintenance Operations:- Normal maintenance operations consist of the following general items:

1. Surface repairs and upkeep.
2. Shoulder and subgrade maintenance.
3. Repair, upkeep, and cleaning of drainage facilities, including ditches, culverts, and appurtenances.
4. Roadside maintenance, including repair and control of erosion, mowing of slopes, control of obnoxious weeds, and maintenance of footpaths, recreation areas, etc.
5. Snow and ice removal and control, and street cleaning
6. Bridge and culvert repair and painting and maintenance of stream beds against hazardous erosion or filling up.

Bridges:- Maintenance operations on bridges consist primarily of painting, cleaning bridge seats, repairing and sealing joints, strengthening and replacing damaged bridge members, and inspecting foundations for dangerous scour conditions and taking the necessary steps to prevent damaging undercutting of piers and abutments. Repair crews also replace worn-out bridge decks and provide any other services necessary to preserve the structural integrity of the bridge.

Culverts:- Culverts have to be kept clean from debris and vegetation. Any scour at ends of culverts or at edge of culvert apron is to be repaired and poor concrete replaced.

Repair and Maintenance of Concrete

I. Durability:- Durability of a material is that property which indicates whether or not the material will endure, even though it may not be subjected to loads sufficient to destroy it. Durability of concrete is affected by (1)alternate wetting and drying, (2) freezing and thawing, (3) heating and cooling, (4) capillary water, (5) deposition of salts by percolating water, (6)dissolving of certain products (principally calcium hydroxide) by the percolating water, (7) the dissolving of the cement by certain acids, and (8) chemical reaction between certain constituents of aggregates and the alkalies in high-alkali portland cements. Concrete is a construction material subjected to many of these items at times.

The first three of these items cause volume changes in the concrete, thus setting up stresses in the concrete when the entire concrete mass cannot expand or contract freely. Owing to the fact that the interior concrete is not drying out or changing temperature as rapidly as that on the exterior, stresses are developed and if the concrete is not strong enough to withstand them, cracks will form. This often happens when the surface of concrete dries very rapidly and the interior does not.

Maximum density of water occurs at 4°C., and as soon as that temperature is reached during a period of lowering temperature, the water in the concrete will begin to expand thus tending to crack the concrete. Concrete subjected to freezing should contain as little water as possible and also have strength to resist the expanding force of the water.

Capillary water is water that will rise in a material against the force of gravity, owing to the small pores in the material. Freshly made concrete, as a rule, contains all the water it can hold, and there is no movement through the capillary pores unless evaporation takes place at a surface exposed to dry air. If there is a source of water at some other surface of the concrete more water will be drawn into the concrete by capillarity. Capillary water may cause the same effects as percolating water.

Percolating water containing alkalies (sulfates) in solution may cause disintegration owing to the combining of the alkalies with certain constituents of the hardened cement, thus forming new compounds of considerably greater volume.

II. **General Requirements for Workmanship:-** In these paragraphs, the approved procedures for repair of imperfections in new concrete are described. These instructions are also applicable, as indicated, to reconstruction of disintegrated portions of structures in service. At first glance it may seem that the procedures are unnecessarily detailed. Actually, experience has repeatedly demonstrated that no step can be omitted or carelessly performed without detriment to the serviceability of the work. If not properly performed, the repair will later become loose and drummy, will crack at the edges, and will not be watertight. It is the obligation of the constructor to repair imperfections in his work so that the repairs will be tight and of a quality and durability in keeping with the adjacent portions of the structure. It is the responsibility of maintenance forces to secure replacements and restorations that will be durable, well bonded to the old concrete, and inconspicuous. Only by scrupulously practicing the following methods in all details can be desired results be assured.

In view of the foregoing considerations and the fact that most repair procedures largely involve manual operations, it is obvious that both foremen and workmen must be fully instructed concerning the procedural details and the reasons for them. Constant vigilance must be exercised to assure maintenance of the necessary standards of workmanship. Employment of dependable and capable workmen is essential.

On new work the repairs which will develop the best bond and thus have the best chance of being as durable and permanent as the original work are those made immediately after early stripping of the forms, while the concrete is quite green. For this reason repairs should be completed within 24 hours after the forms have been removed. Before repairs are commenced, the method proposed for use should be approved by an authorized inspector. Routine curing should be interrupted only in the area of repair operations.

Effective repair of deteriorated portions of structures cannot be assured unless there is complete removal of all affected concrete, careful replacement of the concrete in strict accordance with an approved procedure, secure anchorage, and effective drainage when needed. Consequently, work of this type should not be undertaken unless or until ample time and facilities are available. Only as much of this work should be undertaken as can be completed correctly; otherwise the work should be postponed, but not so long as to allow serious deterioration. Repairs should be made at the earliest possible date.

III. Methods of Repair:-(a) Repair of New Work:- For these repairs three methods are in use:

1. The dry-pack method should be used for holes having a depth nearly equal to, or greater than the least surface dimension; for cone-bolt, and grout-insert holes; and for narrow slots cut for the repair of

cracks. Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained; for filling in back of considerable lengths of exposed reinforcement; nor for filling holes which extend entirely through the wall, beam, or bulkhead, etc.

2. Concrete replacement should be used when holes extend entirely through the concrete section; when holes in unreinforced concrete are more than 1 square foot in area and 4 inches or more in depth; and when holes in reinforced concrete are more than one-half of a square foot in area and deeper than the reinforcement steel.

3. The mortar-replacement method should be used for holes too wide to dry pack and too shallow for concrete replacement; and for all comparatively shallow depressions, large or small, which extend no deeper than the far side of the reinforcement bars nearest the surface.

b) **Repair of Old Work:-** For replacement of deteriorated concrete there are also three approved methods of repair in use. Choice of method is mainly determined by the size of the job. All have proved effective amd will produce durable repairs if proper precautions are observed in doing the work.

1. Prepacked concrete is used advantageously on large repair jobs, particularly when underwater placement is involved or when conventional placing of concrete would be difficult.

2. Concrete replacement, when the concrete can be placed to a minimum depth of 6 inches, is the method best adapted for repair of deteriorated concrete in small areas and in small structures; for the tops of walls, piers, parapets, and curbs; and for refacing walls and relining channels.

3. Mortar replacement, applied as described in sections III and VII of this chapter, may be used for minor restorations of deteriorated work. The repairs may be executed either by use of pneumatically applied mortar from a small gun or by hand methods. In either case the treatment for protection of concrete against weathering should be applied.

For large-scale repair and restoration of old structures, the use of mortar pneumatically applied with standard-sized equipment has been neithere satisfactory nor economical. Well-anchored air-entrained concrete is seldom more costly, is fully as durable, is less subject to cracking, and therefore provides better protection to the old concrete. When pneumatically applied mortar is used on larger areas, its greater expansion and contraction in relation to that of the underlying concrete has a detrimental effect on bond. Observations of many structures restored with mortar indicate that this cracking and loosening of the mortar coat may permit passage of sufficient water to continue the disintegration of the old concrete.

IV. Preparation of Concrete for Repair:- A thorough exploration of the imperfections should be made before repairs are started. All concrete of questionable quality should be removed. Sometimes, concrete in old structures that appears to be sound will slake and soften after a few days' exposure. For this reason replacement of deteriorated concrete should be delayed several days until reexamination of the excavated surfaces confirms the soundness of the remaining concrete. It is far better to remove too much concrete than too little because affected concrete generally continues to disintegrate and while the work is being done it costs but little more to excavate to ample depth.

Often the full nature of the imperfections and the type of repair to be made cannot be determined until the defective material has been removed. Air-driven chipping hammers are most satisfactory for this work, although good work can be done by hand methods. A sawed edge is superior in every way to a chipped edge, and sawing is less costly than chipping if there is much to be done.

Moistening and cleaning are probably the two most important operations affecting the watertightness and permanence of repairs. They are also the most often neglected. The work should be organized and the workmen trained to give proper attention to these details. Surfaces within the trimmed holes should be kept continuously wet for at least several hours, preferably overnight, prior to placing the new concrete. This wetting should be performed in all cases, regardless of whether the repair involves filling of a cone-bolt hole or the largest excavation. It is of paramount importance in the repair of old concrete. The best and most reliable means of obtaining thorough saturation is to pack the holes with wet burlap and to keep the burlap wet by occasional sprinklings.

Immediately before placement of the filling, the hole should be cleaned so as to leave a surface completely free of chipping dust, dried grout, and all other foreign material. A preliminary washing as soon as the chipping and trimming are completed is desirable to remove all loose material. Final cleaning of the surfaces to which the new concrete is to be bonded should be done by wet sandblasting, followed by washing with an air-water jet. Care should be taken to remove any material embedded in the surface by chisels during the trimming. Bond between the new and the old concrete cannot be obtained through a film or coationg of loose material.

In all cases, unnecessary tie wires should be removed from exposed reinforcement. Cleaning of the steel, if necessary, should be accomplished by sandblasting. The prepared surfaces should be inspected for adequacy of trimming, moistening, and cleaning before new material is placed.

a) **Dry Pack:**- For this method of repair, holes should be sharp and square at the surface edges, but corners within the holes should be rounded, especially when watertightness is a requisite. The interior surfaces of holes left by cone bolts, she bolts, etc., should be roughened enough to develop an effective bond; this can be done with a rough stub of 7/8 inch steel-wire rope, a notched tapered reamer, or a star drill. Other holes should be undercut slightly in several places around the perimeter. Holes for dry pack should have a minimum depth of 1 inch.

b) **Concrete Replacement:**- To obtain satisfactory results, the preparation for this method of repair should be as follows:

1) Holes should have a minimum depth of 6 inches in old concrete and 4 inches in new, and the minimum area of the repair should be one-half of a square foot in reinforced and 1 square foot in unreinforced concrete.

2) Reinforcement bars should not be left partially embedded; there should be a clearance of at least an inch around each exposed bar.

3) The top edge of the hole at the face of the structure should be cut to a fairly horizontal line. If the shape of the defect makes it advisable, the top of the cut may be stepped down and continued on a horizontal line. The top of the hole should be cut on a 1 to 3 upward slope from the back toward the face of the wall from which the concrete will be placed. This is essential to permit vibration of the concrete without leaving air pockets at the top of the repair. In some instances, where a hole goes through a wall or beam, it may be necessary to fill the hole from both sides, in which case the slope of the top of the cut should be modified accordingly.

4) The bottom and sides of the hole should be cut sharp and approximately square with the face of the wall. When the hole goes entirely through the concrete sections, spalling and featheredges may be avoided by having chippers work from both faces. All interior corners should be rounded to a minimum radius of 1 inch.

c) **Mortar Replacement:-** When the mortar gun is used with this method, comparatively shallow holes should be flared outwardly at about a 1 to 1 slope to avoid the inclusion of rebound. Corners within the holes should be rounded. Shallow imperfections in new concrete may be repaired by mortar replacement if the work is done promptly after removal of the forms and while the concrete is still green. For instance, when it is considered necessary to repair the "peeled" areas resulting from surface material sticking to steel forms, the surface may be filled using the mortar gun without further trimming or cutting. In the repair of old concrete, the importance of removing all traces of disintegrated material cannot be overemphasized. All places to be repaired should be chipped out to a depth of not less than an inch. Wherever hand-placed mortar replacement is used, the edges of chipped-out areas should be squared with the surface, leaving no featheredges.

V. Use of Dry-Pack Mortar:- Operations should be preceded by a careful inspection to see that the hole is thoroughly clean and slightly wet with but a small amount of free water on the interior surfaces. The surfaces should then be dusted lightly and slowly with cement by means of a small dry brush until all surfaces have been covered and darkened by absorption of the free water by the cement. Any dry cement in the hole should be removed before packing begins. The holes should not be painted with neat cement grout because this would make the dry-pack material too wet, and because the high shrinkage would prevent development of the bond that is essential to a good repair.

Dry pack is usually a mix (by dry volume or weight) of 1 part cement to 2 1/2 parts of sand that will pass a No.16 screen. A mortar patch is usually darker than the surrounding concrete unless special precautions are taken to match the colors. Where uniform color is important, white cement may be used in sufficient amount (as determined by trial) to produce uniform appearance. For packing cone-bolt holes, a leaner mix of 1 to 3 or 1 to 3 1/2 will be sufficiently strong and will blend better with the color of the wall. Only enough water should be used to produce a mortar which, when used, will stick together on being molded into a ball by a slight pressure of the hands; and will not exude water but will leave the hands damp. The proper amount of mixing water and the proper consistency are those which will produce a filling which is at the point of becoming rubbery when the material is solidly packed. Any less water will not make a sound, solid pack; any more will result in excessive shrinkage and a loose repair.

Dry-pack material should be placed and packed in layers having a compacted thickness of about three-eighths inch. Thicker layers will not be well compacted at the bottom. The surface of each layer should be scratched to facilitate bonding with the next layer. One layer may follow another immediately unless appreciable rubberiness develops, in which case work on the repair should be delayed 30 to 40 minutes. Under no circumstances should alternate layers of wet and dry materials be used.

Each layer should be solidly compacted over its entire surface by use of a hardwood stick and a hammer. These sticks are usually 8 to 12 inches long and not over 1 inch in diameter, and are used on the fresh mortar like a calking tool. Hard-wood sticks are used in preference to metal bars because the latter tend to polish the surface of each layer, and thus make the bond less certain and the filling less uniform. Much of the tamping should be directed at a slight angle and toward the sides of the hole to assure maximum compaction in these areas. The holes should not be overfilled, and finishing may usually be completed at once by laying the flat side of a hard-wood piece against the fill and striking it several good blows.

If necessary, a few light strokes with a rag sometime later may improve the appearance. Steel finishing tools should not be used and water must not be used to facilitate finishing.

VI. Procedure for Replacement of Formed Concrete:- The construction and setting of forms are important steps in the procedure for satisfactory concrete replacement where the concrete must be placed from the side of the structure. To obtain a tight and acceptable repair the following requirements must be observed:

1) Front forms for wall repairs more than 18 inches high should be constructed in horizontal sections so the concrete can be conveniently placed in lifts not more than 12 inches in depth. The back form may be built in one piece. Sections to be set as concreting progresses should be fitted before concrete placement is started.

2. To exert pressure on the largest area of form sheathing, tie bolts should pass through wooden blocks fitted snugly between the walers and the sheathing.

3. For irregularly shaped holes, chimneys may be required at more than one level and in some cases, such as when beam connections are involved, a chimney may be necessary on both sides of the wall or beam. In all

cases the chimney should extend the full width of the hole.

4. Forms should be substantially constructed so that pressure may be applied to the chimney cap at the proper time.

5. Forms must be mortartight at all joints between adjacent sections and between the forms and concrete and at tie-bolt holes to prevent the loss of mortar when pressure is applied to the concrete during the final stages of placement. Twisted or stranded calking cotton, folded canvas strips, or similar material should be used as the forms are assembled.

Immediately prior to placing the front section of form for each lift, the surface of the old concrete at the sides which will be covered by new concrete should be coated with a thin layer (about one-eighth of an inch) of mortar. This mortar should have the same sand and cement content and the same water-cement ratio as the mortar in the replacement concrete. The surface should be damp (but not wet) from the required prewetting, sandblasting, and washing, and the mortar may be applied by means of an air-suction gun, by brushing, or by being rubbed into the surface with the hand encased in a rubber glove. Concrete placement should follow immediately.

Concrete for the repair should have the same water-cement ratio as is used for similar new structures. As large a maximum size of aggregate and as low a slump as are consistent with proper placing and thorough vibration should be used to minimize water content and consequent shrinkage. The concrete should contain 3 to 5 percent of entrained air. Where surface color is important, the cement should be carefully selected, or blended with white cement, to obtain the desired results. To minimize shrinkage, the concrete should be as cool as practicable when placed. Materials should therefore be kept in shaded areas during warm weather. Batching of materials should preferably be by weight, but batch boxes, if of the exact size needed, may be used. Since batches for this class of work will be small, the uniformity of the materials is important and should receive proper attention. When placing concrete in lifts, placement should not be continuous; a minimum period of 30 minutes should elapse between lifts. When chimneys are required at more than one level, the lower chimney should be filled and allowed to remain for the 30 minutes between lifts. When chimneys are required on both faces of a wall or beam, concrete should be placed in one chimney only, until it flows through to the other.

Best repairs are obtained when the lowest practicable slump is used. This is about 3 inches for the first lift in an ordinary large form. Subsequent lifts can be drier, and the top few inches of concrete in the hole and that in the chimney should be placed at almost zero slump. It is usually best to mix enough concrete at the start for the entire hole. Thus the concrete will be 1/2 hour, 1 hour, or perhaps 1 1/2 hours old when the successive lifts are placed. Such premixed concrete, provided it can be vibrated satisfactorily, will have less settlement, less shrinkage, and greater strength than freshly mixed concrete.

The quality of a repair depends not only on use of low slump concrete but also on the thoroughness of the vibration, both during and after depositing the concrete. There is no danger of over-vibration. Immersion-type vibrators should be used if accessibility permits. If not, this type of vibrator can be used very effectively on the forms from the outside. Form vibrators can be used to good advantage on forms for large inaccessible repairs, especially on a one-piece back form, or attached to large metal fittings such as hinge-base castings. Immediately after the hole has been completely filled, pressure should be applied to the fill and the form vibrated. This operation should be repeated at 30 minute intervals until the concrete hardens and no longer responds to vibration. In filling the top of the form, concrete to a depth of only 2 or 3 inches should be left in the chimney under the pressure cap. A greater depth tends to dissipate the pressure. After the hole has been filled and the pressure cap placed, the concrete should not be vibrated without a simultaneous application of pressure -- to do so may produce a film of water at the top of the repair which will prevent bonding.

Addition of aluminum powder to concrete causes the latter to expand. Under favorable conditions, this procedure has been successfully used to secure tight, well-bonded repairs in locations where the replacement material had to be introduced from the side. Time should not be allowed for settlement between lifts. When the top lift and the chimney are filled, no pressure need be applied, but the pressure cap should be secured in position so the expanding concrete will be confined to and completely fill the hole under going repair. There should be no subsequent revibration Aluminum powder should not be used until tests with job materials and at job temperatures have shown that effective expansion can be obtained and even then only under strict control. When used, the powder should first be blended with 50 parts, by weight, of cement or pozzolan. To secure the required expansion, more of the blend must be used at low than at moderate or high temperatures.

Concrete replacement in open-top forms, as used for the reconstruction of the tops of walls, piers, parapets, and curbs is a comparatively simple operation. Only such materials as will make concrete of proved durability should be used. The water-cement ratio should not exceed 0.45 by weight. For best durability, the maximum size of aggregate should be the largest practicable and the percentage of sand the minimum practicable. No special features are required in the forms but they should be mortartight when vibrated, and should give the new concrete a finish similar to the adjacent areas. The slump should be as low as practicable, and the dosage of air-entraining agent increased as necessary to secure the maximum permissible percentage of entrained air, despite the low slump. Top surfaces should be sloped so as to provide rapid drainage. Manipulation in finishing should be held to a minimum, and a wood-float finish is preferable to a steel trowel finish. Edges and corners should be tooled or chamfered. Use of water to aid in finishing should be prohibited.

Forms for concrete replacement repairs may usually be removed the day after casting unless form removal would damage the green concrete, in which event stripping should be postponed another day or two. The projections left by the chimneys should normally be removed the second day. If the trimming is done earlier, the concrete tends to break back into the repair. These projections should always be removed by working up from the bottom because working down from the top tends to break concrete out of the repair. The rough area resulting from the trimming should be filled and stoned so as to produce a surface comparable to that of the surrounding areas. Plastering of these surfaces should never be permitted.

VII. **Procedure for Mortar Replacement:-** Best results will mortar replacement are obtained when the material is pneumatically applied using a small gun. Equipment commonly used for pneumatic application of mortar is too large to be satisfactory for the ordinarily small sized repairs of new concrete. Neat work is difficult in the usual small areas and cleanup costs are high because cleanup is seldom done promptly. However, small sized equipment such as the air suction gun fitted with a water ring on the nozzle, has proved satisfactory for small scale repair work. After the areas to be repaired have been prepared by chipping, saturation, sandblasting and washing, and free water has been removed, the mortar should be applied immediately. No initial application of cement, cement grout, or wet mortar should be made.

The mix recommended for the air-suction gun is 1 part cement to 4 1/2 parts natural sand by dry volume or weight. Rebound changes these proportions so that the material in place is much richer. The best results are obtained with a well-graded sand passing the No.16 screen. The cement and sand should be mixed with water to approximately the same consistency as for dry pack repair. If not enough water is used, rebound will be high and the applied mortar too rich, but too much water will cause the gun to plug frequently. When the proper consistency is used, the gun will plug occasionally, but it may readily be cleared by holding the nozzle against the ground or the wall, then tapping the gun and suction hose until the congested material is blown out of the suction hose.

If the repairs are more than 1 inch deep, the mortar should be applied in layers not more than three-quarters of an inch thick to avoid sagging and loss of bond. After completion of each layer there should be a lapse of 30 minutes or more before the next layer is placed. Scratching or otherwise preparing the surface of a layer prior to addition of the next layer is unnecessary, but the mortar must not be allowed to dry.

If a small gun is used in which the water is introduced at the nozzle, care must be exercised to apply mortar of the lowest practicable water content in order to avoid sagging and later shrinkage cracking. Although the gun should not be used extensively to place mortar around reinforcement bars, good repairs can be made in shallow imperfections where relatively little steel is exposed, or where the hole extends but a short distance back of the bars, if the angle of the gun is varied frequently as this part of the hole is being filled.

In completing the repair, the hole should be filled slightly more than level full. After the material has partially hardened but can still be trimmed off with the edge of a steel trowel, the excess material should be shaved off, working from the center towards the edges. Extreme care must be used to avoid impairment of the bond.

Neither the trowel nor water should be used in finishing. A satisfactory finish may be obtained by lightly rubbing the surface with a soft rag.

The repair mortar should be preshrunk by mixing it to a plastic consistency as long in advance of its use as the cement will permit. Depending on mix, cement, and temperature, the time for preshrinking should range from 1 to 2 hours. Trial mixes should be made and aged to determine the longest period of delay that the mortar, after reworking, will have sufficient plasticity to permit application. The mortar should be as stiff as possible and yet permit good workmanship. It is not intended or expected that this relatively stiff, preshrunk mortar should be applied as readily as ordinary plaster.

Immediately prior to application of mortar, the damp surface to which the new mortar is to bond should be scrubbed thoroughly with a small quantity of mortar, using a wire brush. Remaining loose sand particles should be swept away immediately before application of the mortar. The mortar should be compacted into the surface, taking care to secure tight filling around the edges, and shaped and finished to correspond with the undamaged surface.

For minor restorations, satisfactory mortar replacement may be performed by Hand (d); followed by the weatherproofing treatment described in section X. The success of this method depends on complete removal of all defective and affected concrete, good bonding of the mortar to the old concrete, elimination of shrinkage of the patch after placement, and thorough curing.

VIII. **Repairs under Seepage Conditions:** Repairs should not be attempted where there is seeping or running water. When the water cannot be diverted it is often possible, by plugging the outlet with quick-setting mortar, to stop the flow long enough for the repair to be made and to harden. Mortar for plugging such leaks should consist of 1 part cement and 1 to 2 parts sand, by volume. If the mixing water contains 30 to 50 per cent of calcium chloride, or soda ash equal to about 5 per cent of the weight of the cement, the mortar will set in a few minutes while being held tightly in position against the leak. The time of set is determined by the strength of the mixing water solution.

IX. **Curing of Repairs:-** Because of the relatively small volume of most repairs and the tendency of the old concrete to absorb moisture from the new material, water curing is a highly desirable procedure at least during the first 24 hours. When forms are used for the repair they can be removed and then reset so as to hold a few layers of wet burlap in contact with the new concrete. When sealing compound is used, the best curing combination is an initial water-curing period of 7 days followed, while the surface is still damp, by a coat of the compound. In all cases it is essential that repairs even dry-packed cone-bolt holes, receive some water curing and be thoroughly damp before the sealing compound is applied. If nothing better can be devised for the initial water curing of the dry pack in cone-bolt holes and similar repairs, a reliable workman should be detailed to make the rounds with water and a large brush or a spraying device to keep the repaired surfaces wet for 24 hours prior to the application of the sealing coat.

X. Treatment for Protection of Concrete Against Weathering:-

(a) **General Discussion:-** Experience has shown that there are certain portions of exposed concrete structures which are more vulnerable than others to deterioration from weathering in freezing climates. These are the exposed surfaces of the top 2 feet of walls, piers, posts, handrails, and parapets; all of curbs, sills, ledges, copings, cornices and corners; and surfaces which will be in contact with water or spray at frequently changing levels during freezing weather. The durability of such concrete features can be considerably improved and their serviceability greatly prolonged by preventive maintenance in the form of the weather-proofing treatment hereinafter described.

Except for hand-placed mortar restorations of deteriorated concrete (section VII), this weatherproofing treatment is ordinarily not applied on new concrete construction. It is most advantageously used on older surfaces when the earliest visible evidence of susceptibility to weathering appears; that is, before deterioration advances to a stage where it cannot be arrested by the treatment. Such early evidence consists primarily of fine surface cracking close and parallel to edges and corners. Some times the need for protection is indicated by pattern cracking. By treatment of these vulnerable surfaces in the early stage of weathering, later repairs may be avoided, or at least postponed for a long time.

(b) **Preparation of Surfaces:-** After completion of the curing period, a repair should be allowed to dry 1 to 2 weeks before the waterproofing treatment is applied. New mortar and concrete patches should be given a neutralizing wash to prevent saponification of the linseed oil used in the water-proofing treatment. A solution of 0.25 of a pound of phosphoric acid and 0.17 of a pound of zinc chloride to a gallon of water is brushed over the surface and allowed to dry 48 hours. This application is not necessary on old concrete. Rinsing or brushing after the neutralizing wash has dried is unnecessary. Before applying the waterproofing, the repair must be clean and dry. Dust and loose material should be brushed off. Effiorescence may be removed by scrubbing with a 10 per cent solution of hydrochloric acid.

(c) **Treatment of Surfaces:**– After the surface is clean and dry, two coats of linseed oil are applied. The first coat consists of a mixture of 50 per cent raw linseed oil and 50 per cent turpentine, heated to a temperature of 175°F. and applied with an ordinary paint brush. Better results are obtained if the atmospheric temperature is above 65°F. For this reason the work should be done during warm weather. After the first coat has set 24 hours, spots will be evident where the concrete is more porous than the remaining surface. Such areas should be spot treated with the hot mixture and allowed to set 24 hours before the second coat is applied. The second coat consists of undiluted raw linseed oil heated to 175°F. and applied in the same manner as the first.

If there are open cracks in the surface being repaired, a more effective waterproofing may be obtained by filling the cracks prior to applying the second coat of hot oil. A standard mineral paste wood filler, thinned as necessary to secure the desired penetration, may be used for this purpose.

After the second waterproofing coat is thoroughly dry, the entire treated surface should be given two coats of any standard outside white lead and oil paint. Without the protection of this pigmented paint, the oil treatment is subject to rapid deterioration, and its potential value will be seriously impaired. A color resembling concrete can be obtained, if desired, in the paint coats, by addition of lampblack and raw sienna ground in oil. The Oregon standard white paint formula is as follows.

Paint Composition:

	Percent
Pigment, not less than	70
Vehicle, not more than	30

Pigment Composition:

White lead carbonate	40-45
Titanium barium pigment	35-40
Zinc oxide	15-20
Tinting pigment, if required	0-5

Bridge Deck Expansion Joints

Expansion joints in bridge decks are often a problem and need careful inspection. On short span bridges, the bituminous surfacing is carried right over the joint so that the joint is invisible. These are called buried joints.

With temperature changes in moderate climates, a bridge 50 meters long will change its length by about 25 mm (about 1"). In areas with big temperature differences, the change in length will be bigger.

Expansion joints provide space into which the ends of deck slab can protrude when slabs lengthen or shift position. It is a universal practice to provide expansion joints at spacings of 100 ft or less.

Expansion joints are sealed with materials like harder paving and air blown asphalts, sometimes mixed with mineral filler, rubber asphalts and a variety of rubber compounds. Some of these are poured hot and become stiff on cooling, others are placed cold. Preformed strips consisting of strips of extruded neoprene are also used to seal the expansion joints of the bridge deck concrete slab. These are compressed for insertion into the joint groove. After insertion, they expand to completely fill the space. An adhesive causes the strips to adhere to the opposing joint faces.

Repointing Old Masonry

Poor pointing is one of the main problems with masonry. It is caused by expansion and contraction due to temperature changes. Brick masonry expands as it gets wet and con acts as the bricks dry out. Cracks caused by temperature and moisture changes often run through the mortar only.

Concrete blocks, rubble, dressed stone or brick masonry should be repointed with carefully prepared cement:sand mortar composed of one part cement and two parts sand or one part of a combination of portland cement and hydrated lime and two parts sand. If lime is used it shall not exceed 10 per cent of cement by weight. The cement and sand may be dry mixed in a mixer until colour of the mixture becomes uniform, after which Water shall be added as the mixing continues until the mortar attains the desired consistency. Sand should pass a No.20 sieve, and not less than 40 per cent of it should be retained on a No.50 sieve.

Repointing Concrete Masonry

Any "honeycombed," weathered or disintegrated areas in the concrete shall be cut out and thoroughly cleaned of all loose concrete, dirt or other foreign material to the depth and over the area necessary to procure a firm and solid connecting surface for the adherence of the new mortar. This prepared surface shall then be wetted, filled with mortar well driven in, and finished neatly.

Where the surface must be cleaned out to such depth and area that the new mortar will not stay in place without support, a form shall be placed over the area and the space so enclosed filled with mortar, well rodded in.

Repointing Rubble Masonry

All spaces around the rubble aggregate, after being cleaned, shall be well filled with mortar. If any of the rubble is loose it shall be settled into place before the mortar has set.

Repointing Dressed Stone and Brick Masonry

The joints in the masonry shall be thoroughly cleaned of all loose mortar and foreign material for a depth of at least twice the width of the joint. The joints shall then be filled with mortar, well driven in and neatly finished.

Cleaning and Protection

After repointing is complete and the mortar has set the surface shall be cleaned and left with a neat and work manlike appearance.

PART III

BRIDGE INSPECTION FORMS

PART III. BRIDGE INSPECTION

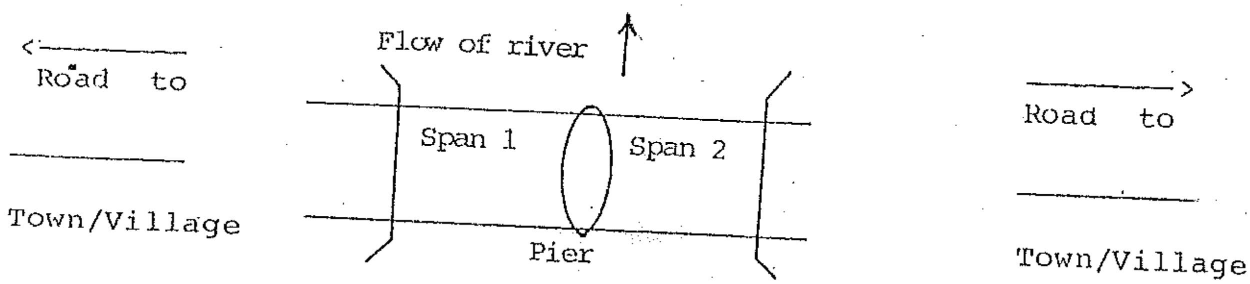
REPORT FORM

Number ______________________ Name ______________________

Crossing ____

Kilometer ____________ on the ____________ to ____________ road

View Looking from above



Inspected by ______________________ Date ______________________

Number of pages in report
(Including sketches, notes, photos) ______________________

Report
accepted by ______________________ Date ______________________

Item No.	Item Description	Field Notes		
		Yes	No	
	Identification			
1	Structure Number			
2	Province and District			
3	Name of Road			
4	Name of Road Section			
5	Route System National Provincial District Council Farm to Market Other			
6	Route/National Highway Number			
7	Kind of Structure Bridge Multiple Culvert Overpass Over road Overpass Over railroad Underpass under road Underpass under railroad			
8	Structure's location Kilometer on the ——— to ——— road			
	Physical Features			
9	Structure's Length (Meters)			
10	Surface Width (meters)			
11	Number of Lanes			
12	Superstructure Material			
13	Deck Material			
14	Substructure Material			
15	Vertical Clearance (Meters)			
16	Horizontal Clearance (Meters)			

No.	Item Description	Field Notes		
		Yes	No	
17	Vertical underclearance (Underpass) (Meters)			
18	Horizontal underclearance (Underpass) (Meters)			
19	Load Class Imp/M.Tons			
20	Details of Services on Bridge • Telephone • Electricity • Gas • Water pipeline • Sewer line • Oil pipline			
21	Traffic Signs •			

No.	Item Description	Field Notes		
	CONDITION	Yes	No	
	Road approaches and Deck			
22	Road Surface near Bridge • Bumpy road surface			
23	Drainage • Badly built road drainage near Bridge • Blocked/damaged road drains • Water on deck • Blocked/damaged deck drains			
24	Bridge and footpaths bitmen surface • Surface breaking up or lifting off • Cracking above joints			
25	Bridge and footpaths concrete surface • Cracking • Spalling • Reinforcement exposed • Poor Concrete • Wear of surface due to small stones			
26	Steel Surface • Fixings loose or damaged • Bends in panels • Corrosion			
27	Timber Surface • Dirt or plants between boards • Decay • Insect attack • Splitting of Timber • Loose or damaged fixings			

Item No.	Description	Field Notes Yes	No	
28	Timber running strips • Damage to running strips • Loose or damaged fixings			
29	Railway or Tram Rails • Loose rail fixings			
30	Kerbs • Damaged or loose kerbs			
31	Foot paths • Damaged footpaths			
32	Parapet, Railings and Guard Rails • Impact damage • Loose or damaged fixings • Loose post base			
33	Steel or Aluminium Parapets • Damaged galvanising or paint • Corrosion			
34	Concrete Parapets • Cracking • Spalling • Corrosion of reinforcement • Poor concrete			
35	Timber Parapets • Decay • Insect attack • Splitting of Timber			
36	Masonry Parapets • Cracking • Movement or bending of parapet • Poor pointing • Deterioration of the bricks or stone work.			

Item No.	Item Description	Field Notes		
		Yes	No	
37	Expansion Joint at Side Abutment or Pier No. • Damage to concrete of deck end or ballast wall near joint • Debris or vegetation in joint • Loose or damaged fixings • Damage or Corrosion to metal parts • Damage to rubber waterbars			

Item No.	Item Description	Yes	No	Field Notes
	RIVER			
38	Blockages in Waterway			
	• Debris against piers or abutments			
	• Remains of old bridges under or upstream of the bridge			
	• Fencing or buildings under bridge			
	• Trees or bushes growing under bridge			
39	Change of River Path			
	• River changing path upstream from bridge			
	• New Islands forming upstream of bridge			
40	River Training Works			
	• River attack beyond the upstream end of the river training works			
	• Damage to sheet piled walls			
	• Loss of rip rap			
	• Damage to Gabions, timber fencing etc.			
	• Damage to trees			

Item No.	Item Description	Field Notes		
		Yes	No	
	SUPERSTRUCTURE			
	Span No.			
41	General • Impact damage to beams, girders, trusses or bracings • Debris or vegetation on beams, girders, trusses or bracings or in joints • Water coming through the deck • Water from deck drainage flowing onto girders, trusses, beams or bracings • Not enough headroom for Overbridge			
	Main Beams, Girders, Trusses and Bracings			
42	Concrete Beams • Cracking • Spalling • Corrosion of reinforcement • Poor concrete			
43	Steel Girders and Bracings • Deterioration of paint or galvanising • Corrosion • Bends in web, flanges, stiffeners or Bracings • Loose bolts or rivets • Cracking			

No.	Item Description	Yes	No	Field Notes
	Span No.			
44	Steel Trusses			
	• Deterioration of paint or galvanising			
	• Corrosion			
	• Bends in truss members			
	• Bent or damaged joints			
	• Bent or damaged bracings			
	• Loose bolts or rivets			
	• Cracking of steel members			
45	Timber Beams			
	• Decay			
	• Insect attack			
	• Splitting of Timber			
	• Separation of laminations on glue laminated beams			
	• Loose or corroded nails, spikes or fixing wires			
46	Timber Trusses			
	• Decay			
	• Insect attack			
	• Splitting of timber			
	• Loose deck to truss connection			
	• Loose or corroded bolts or pins at joints			
	• Bends in truss timbers			
	• Damaged or corroded steel parts			

Item No.	Item Description	Yes	No	Field Notes
	Span No.			
	Under Side of Deck			
47	Concrete			
	• Cracking			
	• Spalling			
	• Corrosion of reinforcement			
	• Poor concrete			
	• Not enough cover to reinforcement			
48	Steel			
	• Deterioration of paint or galvanising			
	• Corrosion			
	• Bends in stringers or plates			
	• Loose bolts or rivets			
	• Cracking			
49	Timber			
	• Decay			
	• Insect attack			
	• Split timbers			
	• Loose or corroded bolts or pins			
50	Masonry jack arch decks			
	• Change of shape of arch			
	• Cracking or spalling			
	• Poor pointing			

No.	Item Description	Yes	No	Field Notes
	BEARINGS			
	Abutment Name			
51	All Bearings			
	° Debris or vegetation around bearings			
	° Bad drainage to bearing shelf			
	° Not enough room for bridge span to move			
	° Bearing not seated properly			
	° Bridge span not seated properly on bearing			
	° Damaged bedding mortar			
52	Rubber Bearings			
	° Splitting, tearing or cracking of rubber			
	° Damaged or loose bolts or pins at fixed bearings			
53	Metal Bearings			
	° Parts not properly seated			
	° Parts not free to move			
	° Problem with the lubrication system			
	° Sliding surfaces damaged			
	° Cracks or bends in metal parts			
	° Corrosion of metal parts			
54	Earth quake Restraints			
	° Damaged or loose earthquake restraints			

Item No.	Item Description	Field Notes		
		Yes	No	
	Span No.			
55	Masonry Arches			
	• Change of shape of arch			
	• Cracking of arch barrel			
	• Cracking or bulging of spandrel walls			
	• Spandrel walls separating from arch			
	• Spalling of stones or bricks			
	• Poor pointing			
	• Water leaking through arch			
	• Scour under arch foundations			

Item No.	Item Description	Yes	No	Field Notes
	Span No.			
56	Bailey Bridges			
	• Missing safety pins			
	• Missing panel pins			
	• Missing or loose bolts			
	• Missing rakers or tie plates			
	• Missing or loose sway braces			
	• Missing, loose or damaged horizontal bracing frames			
	• Missing or loose transom clamps			
	• Wear at stringer to transom seating			
	• Cracking			
	• Bends in members			
	• Deterioration of paint or galvanising			
	• Corrosion			
	• Settlement of bearings			
	• Damage to bearings or base plates			
	• Maximum vertical sag			
	• Maximum horizontal bend			

Item No.	Item Description	Field Notes: Yes	No	
	Abutment, Wing walls and Retaining Walls			
	Abutment Name			
57	Abutment, wing walls and retaing walls			
	° Erosion or scour near abutment			
	° Damage to caissons or piles			
	° Movement of abutment			
	° Debris against abutment			
	° Vegetation growing on or in abutment			
	° Scour near to retaining walls			
	° Movement of retaining walls			
	° Water leaking down through the expansion joint			
58	Drainage System			
	° Not enough weepholes			
	° Weepholes not working			
	° Water leaking through the abutment			
59	Concrete Abutments, Wing Walls and Retaining Walls			
	° Cracking			
	° Spalling			
	° Corrosion of reinforcement			
	° Poor concrete			

No.	Item Description	Yes	No	Field Notes
	Abutment, Wing walls and Retaining wall			
	Abutment Name			
60	Masonry Abutments and Retaining Walls • Cracking • Bulging • Poor pointing • Deterioration of bricks or stones			
61	Gabion Abutments and Retaining Walls • Settlements or bulging of gabions • Damage to gabion wires or ties			
62	Timber Abutments and Retaining Walls • Decay • Insect attack • Splitting of Timber • Loose or corroded binding cables • Loose or corroded fixing spikes			

Item No.	Item Description	Yes	No	Field Notes
	Embankments			
	Abutment Name			
63	General			
	• Scour at base of slopes			
	• Slip of fill			
	• Erosion of fill			
	• Cracking of road or embankment edge			
	• Piping failures of fill			
64	Piled Walls			
	• Forward movement			
	• Deterioration of piles			
65	Stone Pitching Slope Protection			
	• Cracking			
	• Poor pointing			
	• Scour or erosion at edge			
	• Pieces broken off			
66	Gabion Slope Protection			
	• Too much movement of Gabions			
	• Damage to gabion wires or ties			
67	Rip Rap Slope Protection			
	• Rip rap being washed away			
	• Bed settlement			

Item No.	Item Description	Yes	No	Field Notes
	The River Bed			
68	Bed Protection • Large holes in river bed			
69	Stone pitching or concrete Bed Protection and Aprons • Scour at edge • Cracking • Spalling or stones missing • Erosion of surface • Corrosion of reinforcement			
70	Gabion Bed Protection And Aprons • Gabions broken away from pier or abutment • Damage to wires and ties			
71	Rip Rap Bed Protection • Loss of rip rap			

Item No.	Item Description	Field Notes		
		Yes	No	
	Piers			
	Pier No.			
72	General ° Scour near base of pier ° Damage to caissons or piles ° Movement of pier ° Impact damage ° Debris against pier ° Vegetation growing on pier ° Water leaking past expansion joint			
73	Concrete Piers ° Cracking ° Spalling ° Corrosion of reinforcement ° Poor concrete			
74	Masonry Piers ° Cracking ° Poor pointing ° Deterioration of masonry			

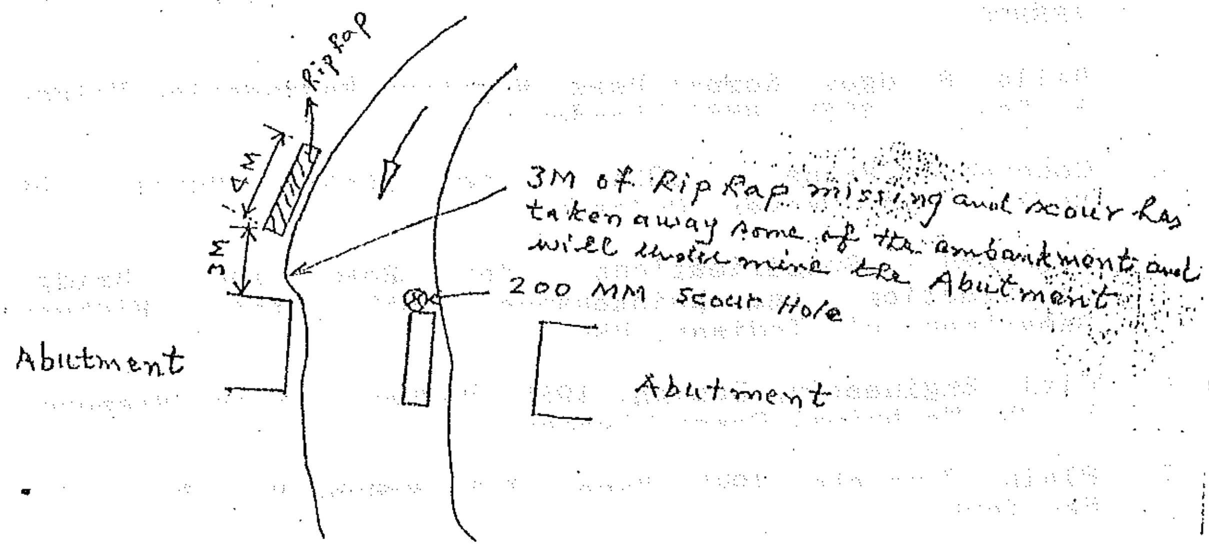
Item No.	Item Description	Field Notes		
		Yes	No	
	Piers			
	Pier No.			
75	Steel Piers ° Debris in joints ° Deterioration of paint or galvanising ° Corrosion ° Bends in steel members or at joints ° Loose bolts or rivets ° Cracking			
76	Timber Piers ° Debris in joints ° Decay ° Insect attack ° Splitting of Timber ° Loose bolts or pins at joints ° Bends in pier timbers ° Damaged or corroded steel parts			

No.	Item Description	Yes	No	Field Notes
	Culverts			
	Also Fill Items 1 to 37 as required			
77	General ° Debris, vegetation, etc in or near culvert ° Settlement of parts of the culvert ° Scour at ends of culvert or at edge of apron			
78	Concrete Culvert Barrels ° Cracking ° Spalling ° Corrosion of reinforcement ° Poor concrete			
79	Corrogated Steel Culverts ° Change of shape of culvert barrel ° Damage or deterioration to paint or galvanising ° Corrosion of steel ° Loose or corroded bolts			
80	Culvert Aprons ° Cracking and damage to concrete or stone pitching ° Damage to Gabions			
81	Headwalls ° Movement of headwall ° Concrete: cracking, spalling, corrosion of reinforcement or poor concrete ° Masonry: cracking, poor pointing or deterioration of bricks or stones			

Office Assessment of Inspection

Note 1

Bridge Inspection



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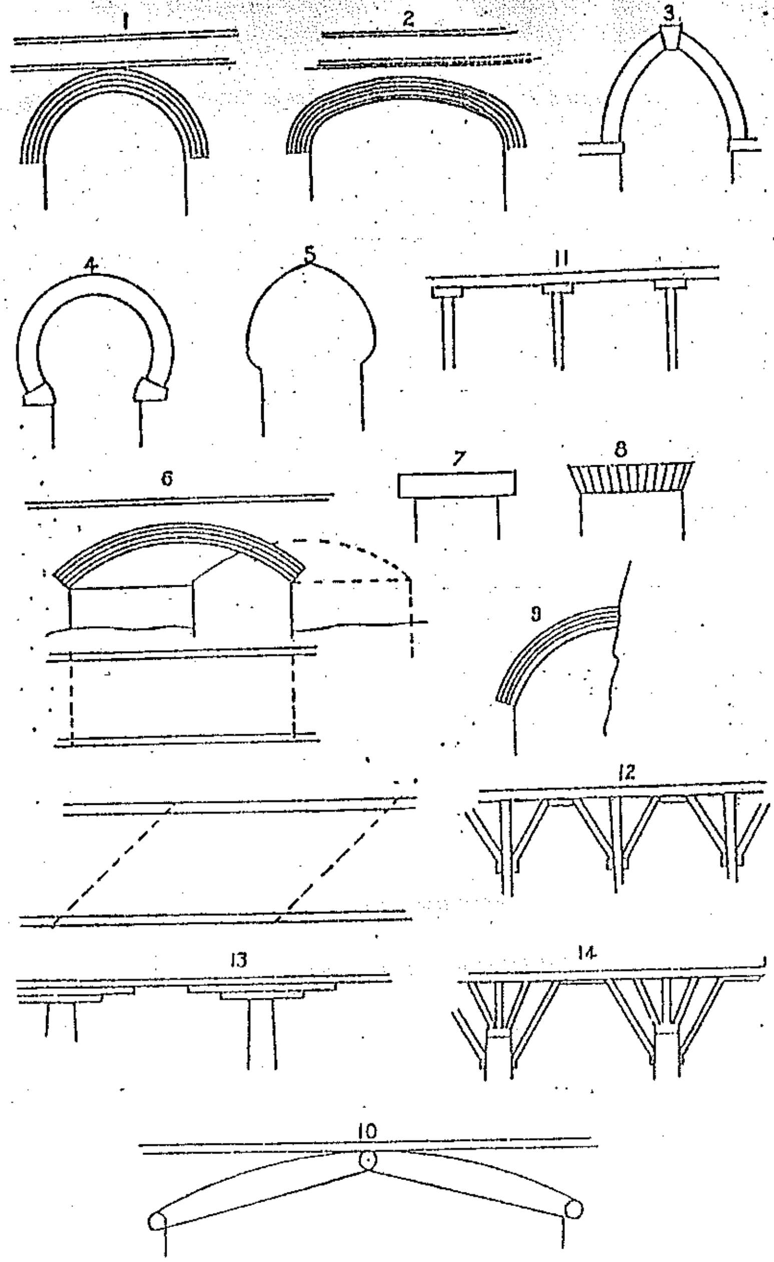
APPENDIX

TYPICAL BRIDGES

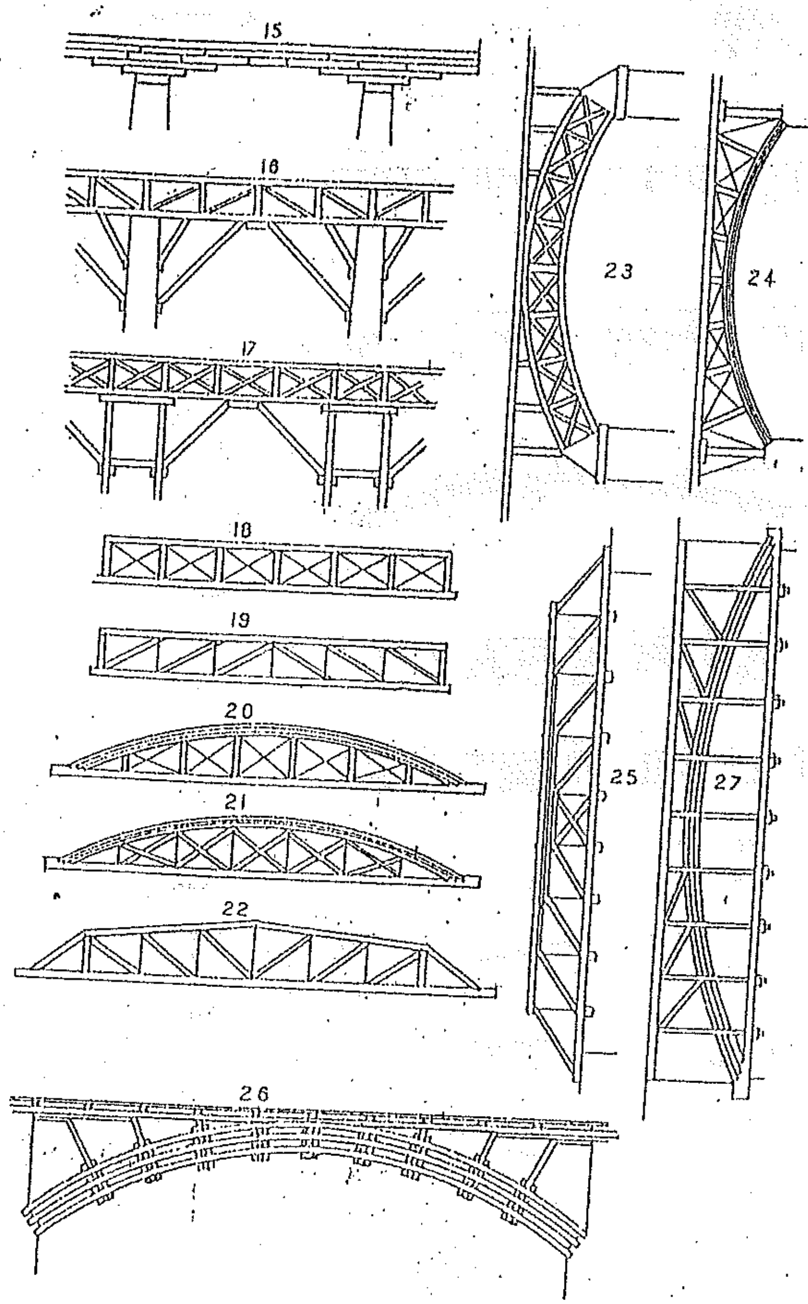


MASONRY BRIDGES

1. Semicircular arch.
2. Elliptical arch.
3. Gothic arch.
4. Byzantine arch.
5. Moorish arch.
6. Skew arch bridge.
7. Lintel over door or window.
8. Flat brick arch.
9. Semi-arch.
10. Three-hinge arch bridge.

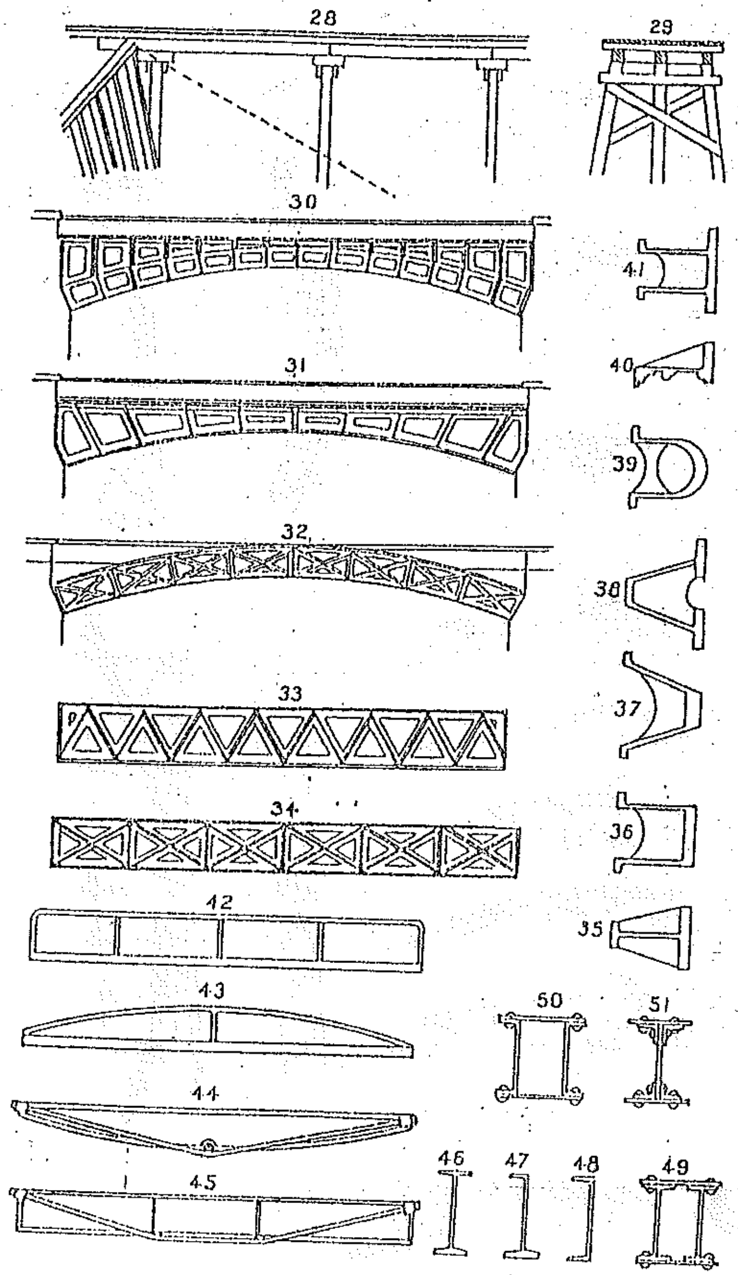
TIMBER BRIDGES

11. Simple pile and girder bridge or gantry.
12. Pile and girder bridge or gantry with struts.
13. Horizontal stepped-timber girder bridge.
14. Timber girder bridge with double struts and masonry piers.



TIMBER BRIDGES

15. Horizontal stepped-timber girder on masonry piers.
16. Braced timber girder, double strutted and carried on masonry piers.
17. Similar bridge, but on double piers.
18-22 Timber-braced girder bridges. The bracing may be wholly wood or wholly or partly steel.
23-4 Arched timber bridges, braced.
25. Timber-braced girder with vertical steel ties.
26. Timber arch bridge with laminated arch and radial struts.
27. Combined bowstring and horizontal braced girder bridge.



TIMBER BRIDGES

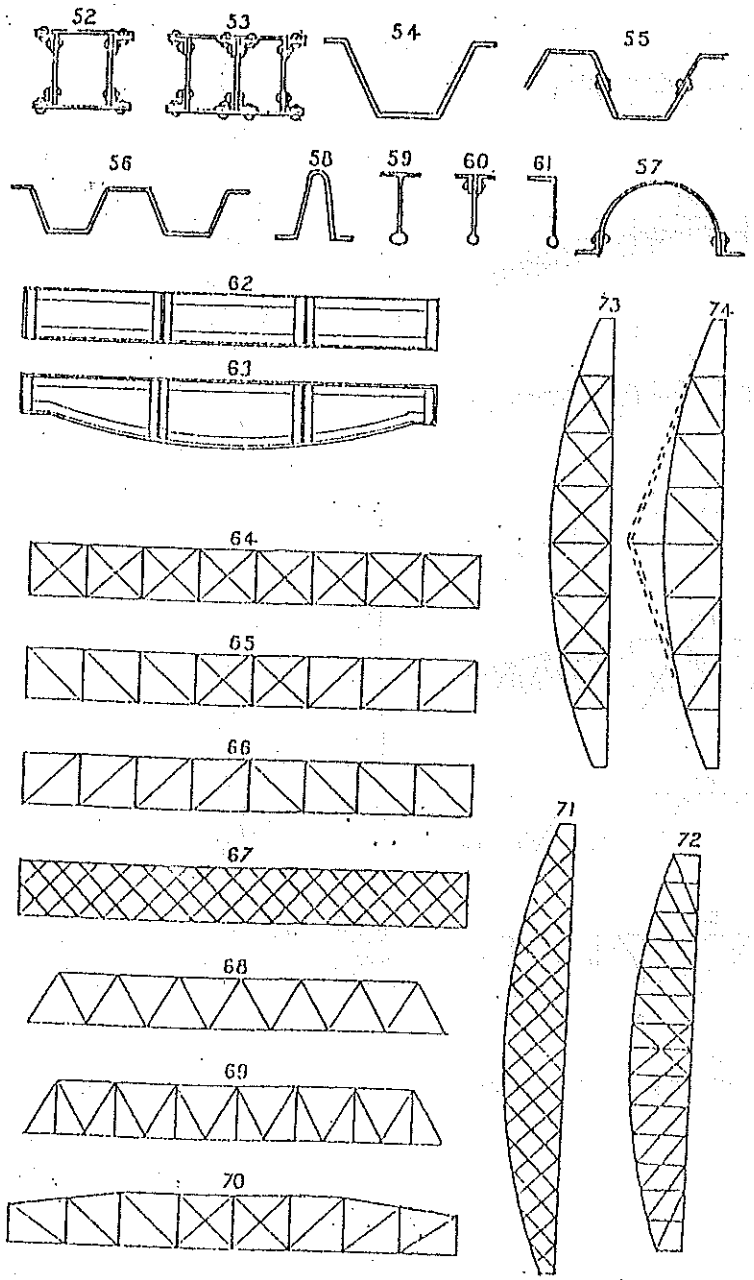
28 Timber gantry or viaduct with timber wings to support an embankment or abutment.
29 Cross section of ditto.
30-2 Cast-iron bridges.

CAST-IRON BRIDGES

33-4 Cast-iron braced girders.
35-41 Cross-sections of various types of cast-iron girders.
42 Cast-iron girder with parallel flanges.
43 Ditto, with curved top flange.
44 Cast-iron fish-bellied girder with steel truss rods.
45 Cast-iron girder with steel truss rods.

STEEL GIRDERS

46-8 Sections of rolled steel girders.
49-51 Sections of built-up girders formed of rolled girders, channels, angles, and plates.



STEEL GIRDERS

52-3 Sections of built-up girders, formed of rolled girders, L irons, and plates.

54-7. Sections of pressed steel troughs for bridge floors. Small bridges are frequently constructed of troughs across the span as girders.

58-61 Bulb and U steel girders.

62 Plate girder with parallel flanges.

63 Ditto, with fish-belly bottom flange.

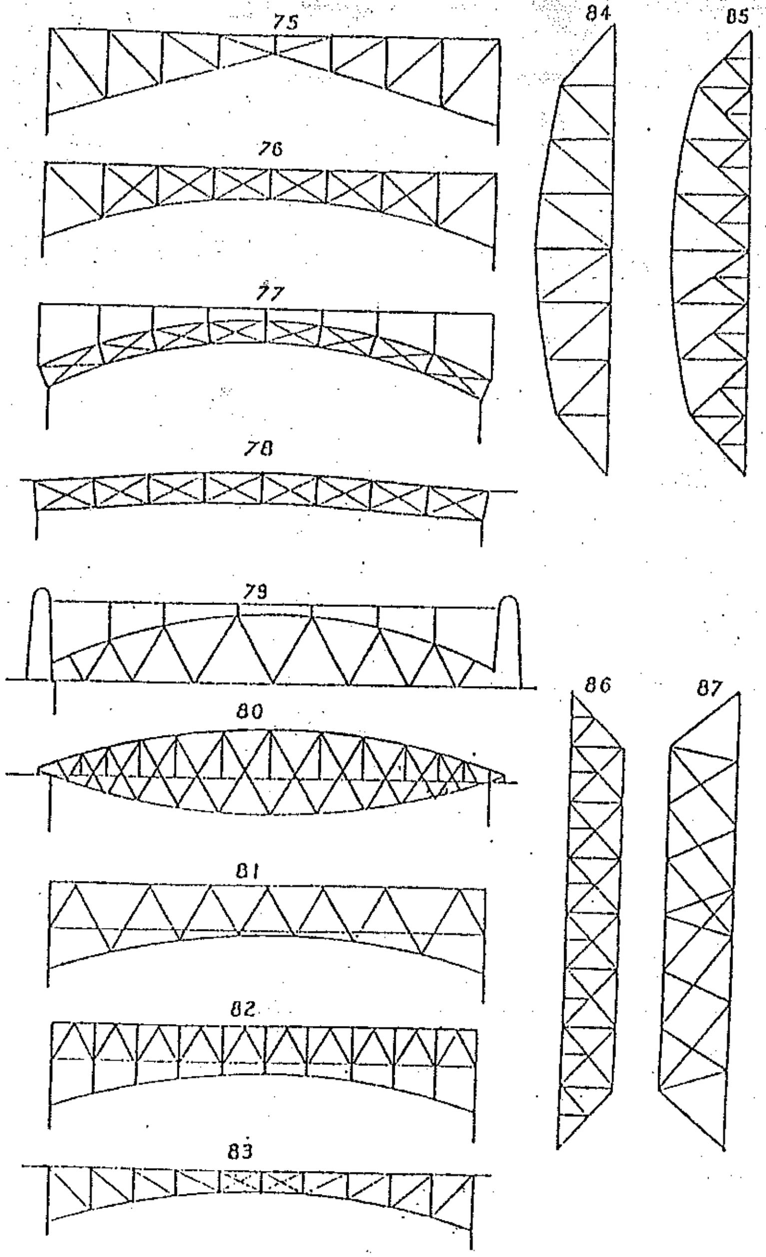
STEEL BRIDGES

64-6 Braced girders with horizontal flanges.

67 Lattice girder.

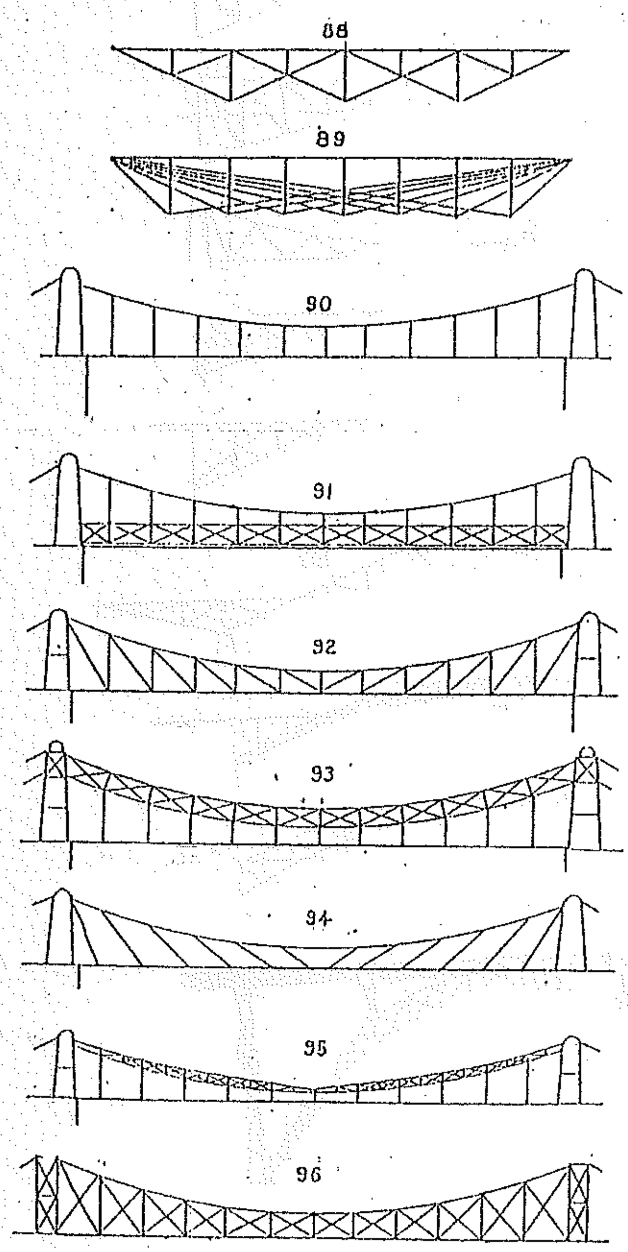
68-9 Warren girders.

70-4 Bowstring braced girders. In No.74 the dotted lines show a method of strengthening the top flange sometimes employed.



STEEL
BRIDGES

75-8 Braced arched girders.
79 Combined horizontal and Warren type bowstring girder.
80 Bowstring and fish-belly braced Warren type girder.
81-3 Braced arched girders.
84-5 Bowstring girder bridges.
86 Trussed braced girder.
87 Diagonal braced American type girder.

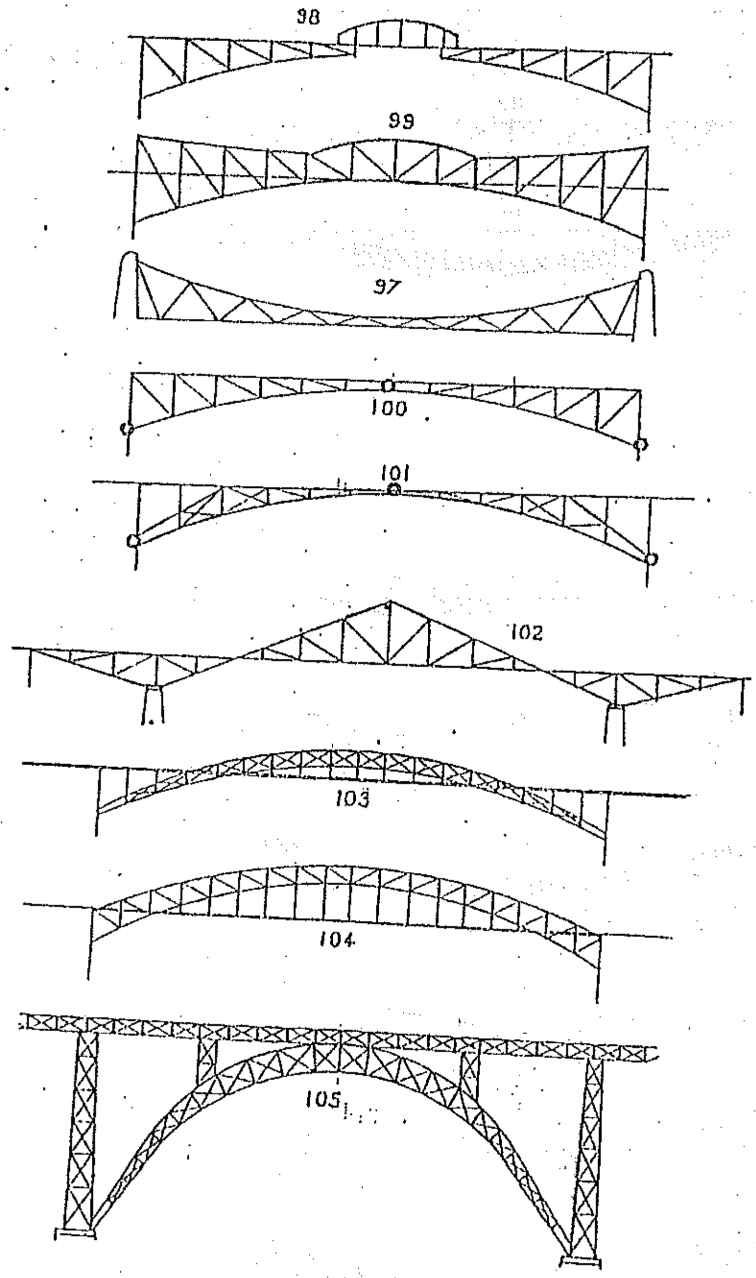


STEEL BRIDGES

88-9 Trussed braced girders.

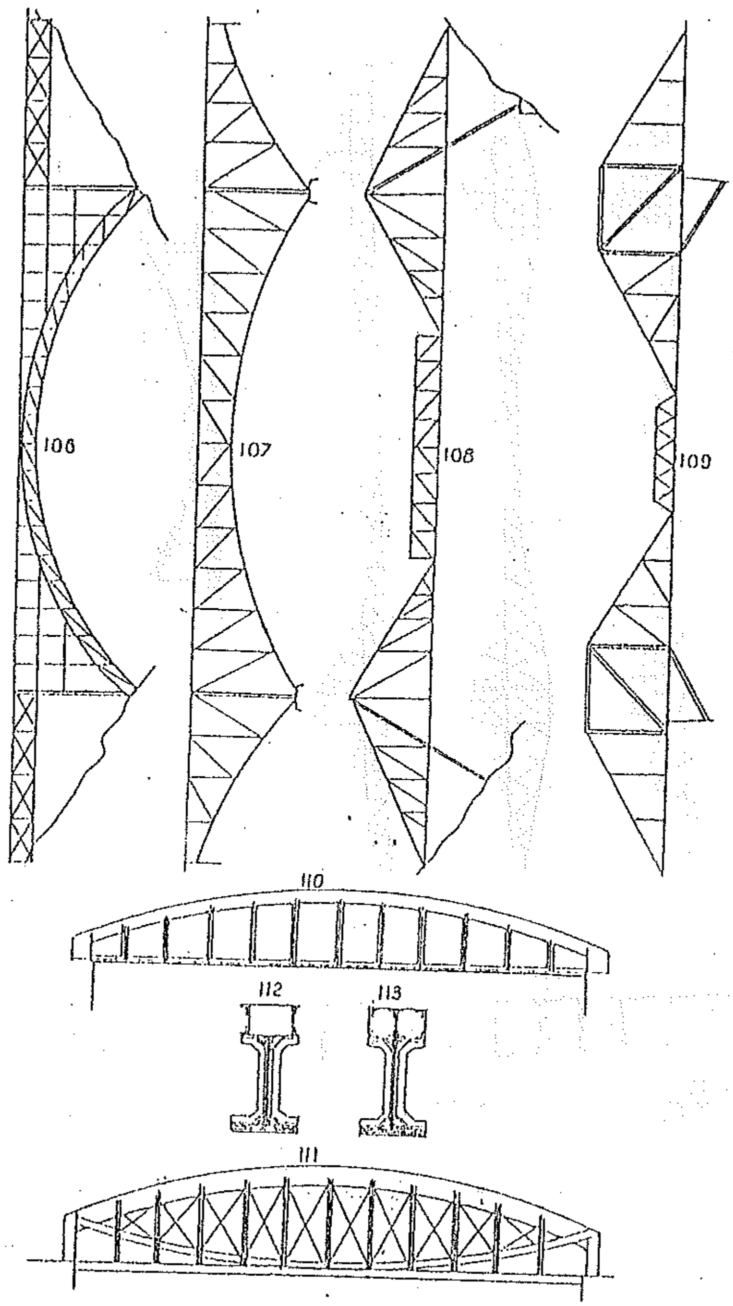
SUSPENSION BRIDGES

90 Ordinary catenary suspension bridge with vertical ties.
91 Suspension bridge with braced horizontal boom.
92 Ditto with diagonal and vertical ties.
93 Ditto with braced catenary.
94 Ditto with diagonal ties.
95 Ditto with braced catenary.
96 Ditto with counterbraced vertical ties (or struts).



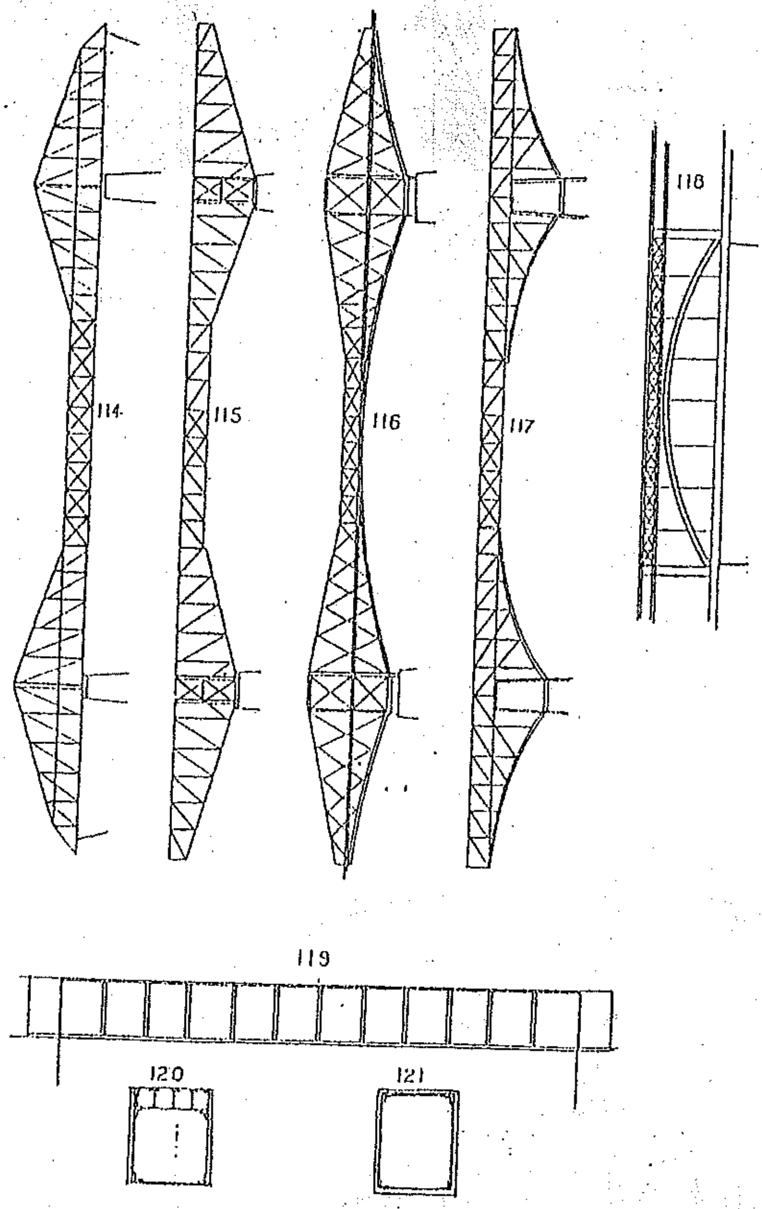
CANTILEVER/
SUSPENSION
BRIDGES

97 Suspension bridge with Warren type bracings.
98-9 Cantilever bridges with central girder.
100-1 Braced arch bridges.
102 Centre and two-side spans, cantilever continuous.
103-5 Braced arch bridges.



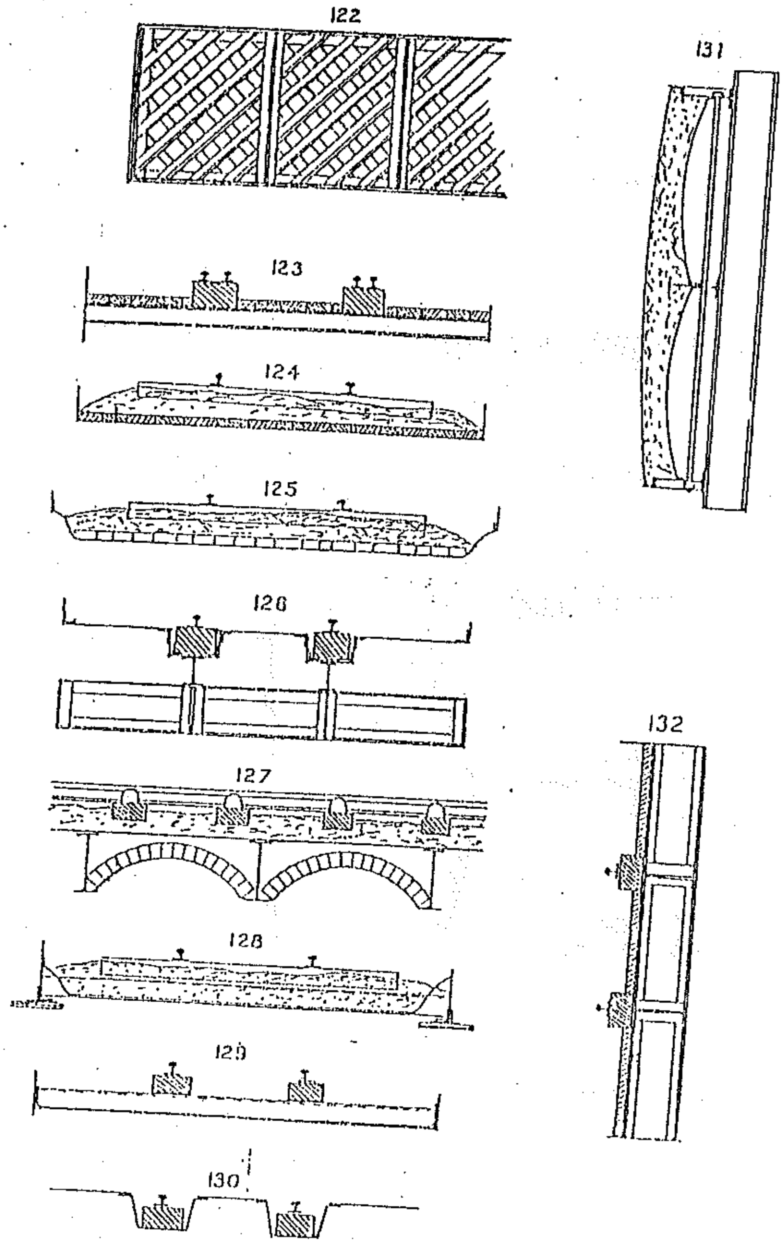
ARCH/ CANTILEVER BRIDGES

106 Braced arch bridge with two side spans.
107 Arched centre span and two semi-arch side spans.
108 Double cantilever bridge with diagonal pier struts and central girder.
109 Another form of the last.
110 Bowstring tubular plate girder bridge with tubular top boom.
111 Braced bowstring girder with tubular top boom.
112-13 Sections of the last two.



CANTILEVER BRIDGES

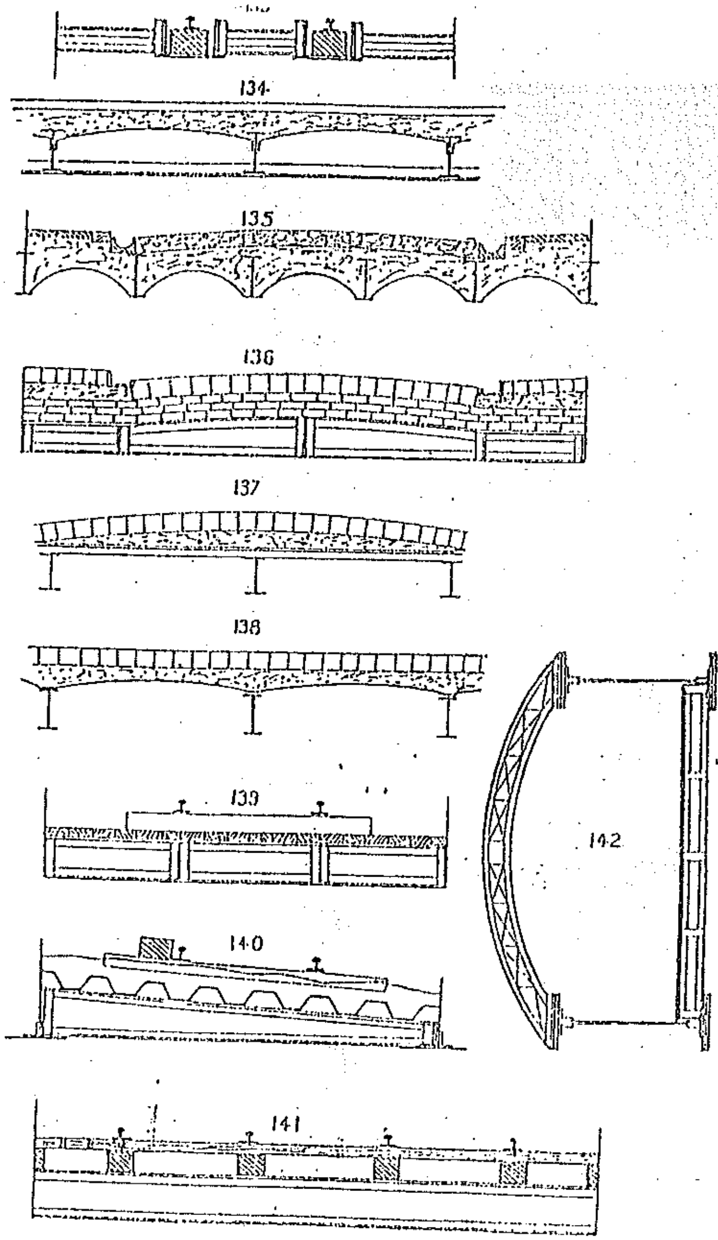
114 Double cantilever bridge with vertical and diagonal bracing and central girder.
In the last three types the roadway is carried on the lower horizontal boom.
115 Ditto with horizontal top boom forming the roadway.
116 Ditto with arched top and bottom booms.
117 Ditto with arched bottom boom.
In the last two types the roadway is carried on the vertical braces.
118 Combined horizontal and bowstring bridge with vertical ties.
119 Tubular plate girder bridge.
120 Section of the last with cellular top boom.
121 Ditto with stiffened top boom.



BRIDGE FLOORS

122 Lattice girder.

123 Longitudinal plank flooring on rolled cross girders.
124 Longitudinal plank floor, covered with asphalt and ballast, banked for a curved line of sleeper railway.
125 Transverse flat or trough plates, covered with asphalt, old bricks, and ballast for sleeper railway.
127 Longitudinal section of floor constructed of rolled cross girders with arched brick filling, carrying asphalt and ballast for a sleeper railway.
128 Transverse troughs (see Nos.54-6) filled with ballast for a sleeper railway.
129 Ditto carrying longitudinal sleeper railway.
130 Longitudinal troughs carrying longitudinal sleeper railway.
131 Ditto on arched plates riveted to longitudinal rolled girders carried on cross girders.
132 Plate girders, transverse and longitudinal, supporting plank flooring and longitudinal rail sleepers.



BRIDGE FLOORS

133 Longitudinal sleepers supported in longitudinal troughs carried by cross girders.

134 Transverse rolled girders supporting arched plates and ballast for a railway.

135 Carriage roadway and two footways of wood or granite setts with concrete channels, carried on planking and longitudinal girders, with concrete arched filling.

136 Ditto with cast-iron channels laid on three thicknesses of planking on cambered cross girders.

137 Cambered roadway of wood or granite setts on cast-iron plates and longitudinal rolled girders.

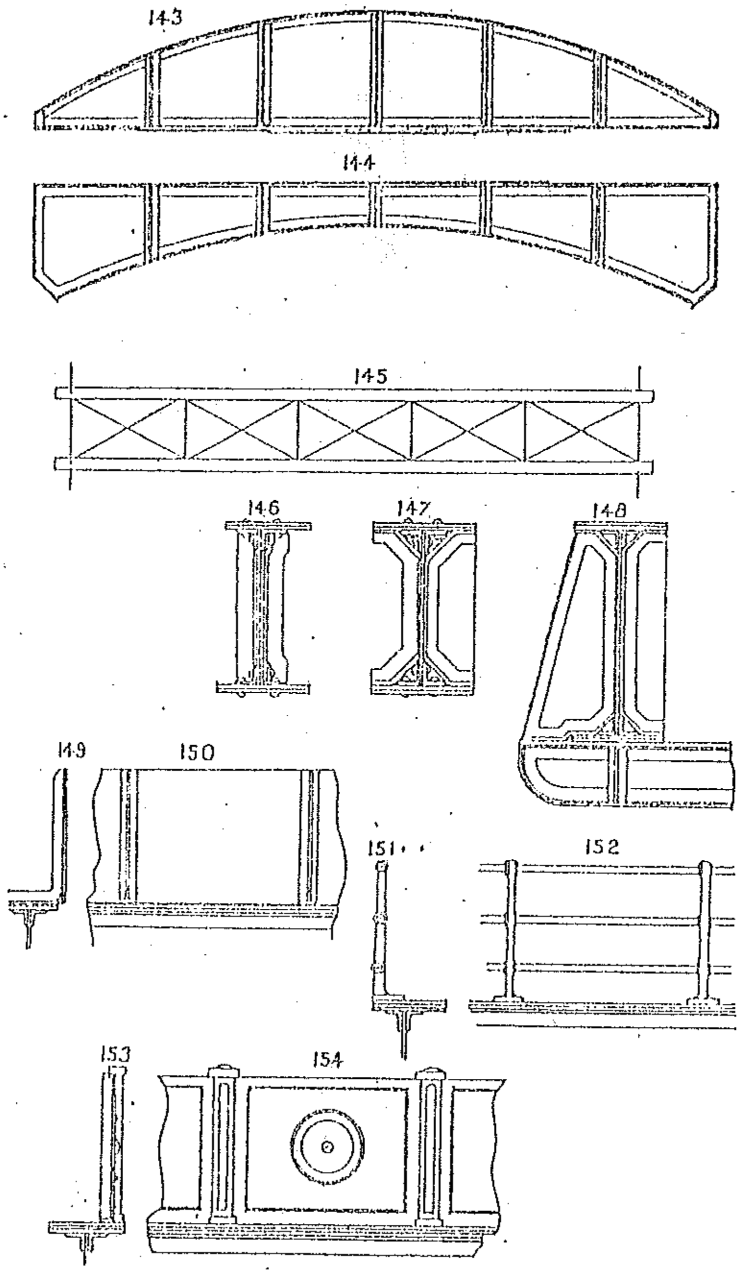
138 Ditto on arched steel plates and cross girders.

139 Sleeper railway on longitudinal plank floor carried on cross girders.

140 Sleeper railway banked for a curved line on ballast and longitudinal trough plates and sloping cross girders.

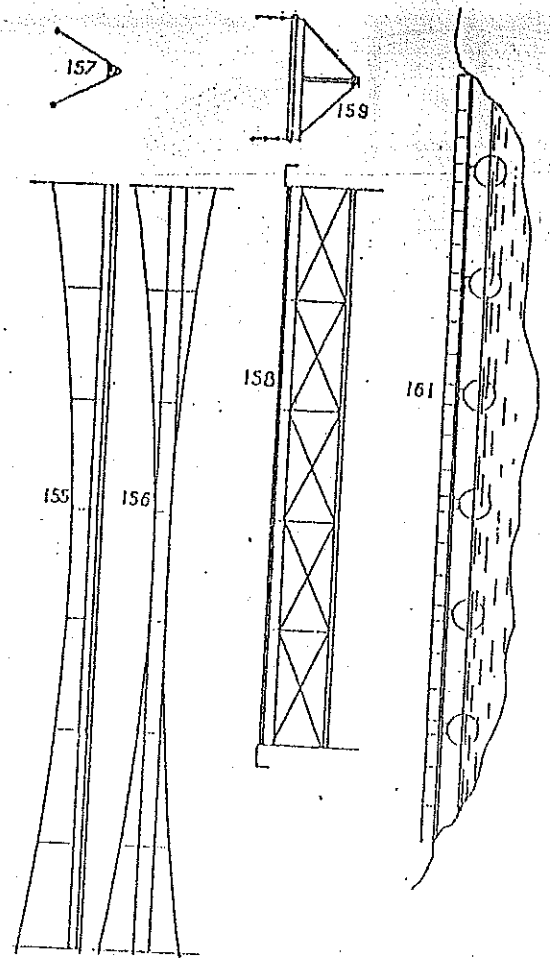
141 Double line of flange rails on plank floor supported on four longitudinal sleepers and cross girders.

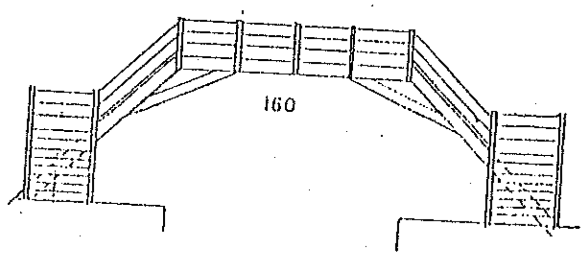
142 Transverse section of a girder bridge having transverse arched top bracing.



BRIDGE GIRDERS

143 Bowstring plate girder.
144 Arched plate girder.
145 Plan of girder bridge with diagonal wind bracing.
146-8 Sections of plate girders.
149-50 Platework and T standard parapet.
151-2 Tube rail bridge parapet, with cast or wrought-iron standards.
153-4 Cast-iron panelled parapet.





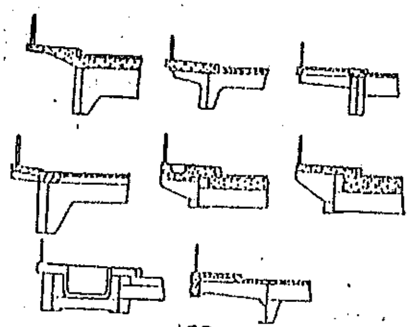
FOOT/
PONTOON
BRIDGES

155-7 Elevation plan and section of light rope suspension bridge.

158-9 Braced bridge of triangular cross section.

160 Type of railway crossing footbridge in timber or steel.

161 Pontoon bridge on boats, pontoons, rafts, or barrels.



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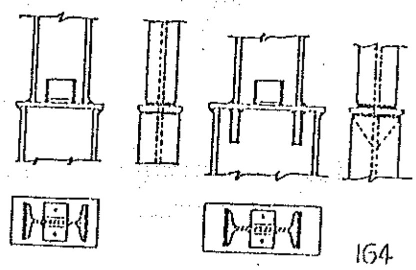

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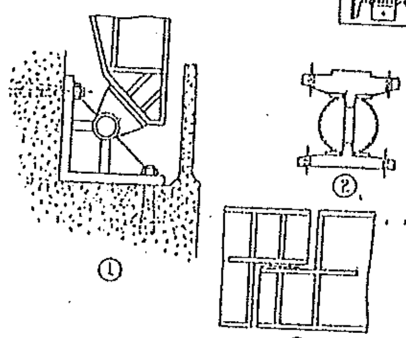

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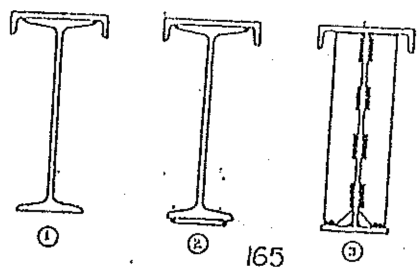


165

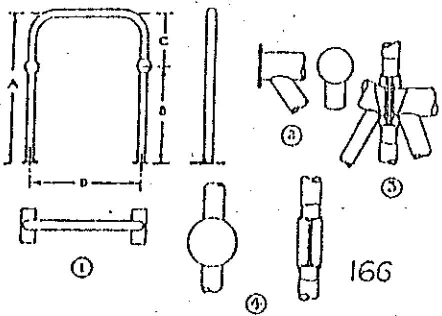
WELDED BRIDGES

162. Welded road bridges. Typical cross-sections of alternative designs.

163 Details of welded bridges: (1) Fixed bearing; (2) Typical expansion bearing; (3) Bearing at end of cantilever.

164 Bridges and girders. Welded splices for columns of variable section, with no bending. Black solid circles indicate holes for erection bolts.

165 Welded crane gantry girders. Alternative designs: (1) I-beam and channel; (2) Plated I-beam and channel; (3) Built-up girder with flat or angle stiffeners.



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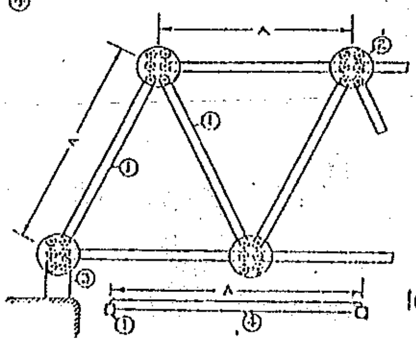

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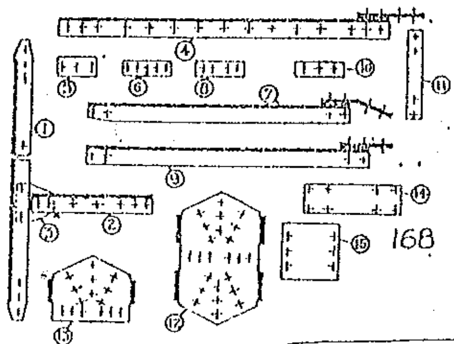

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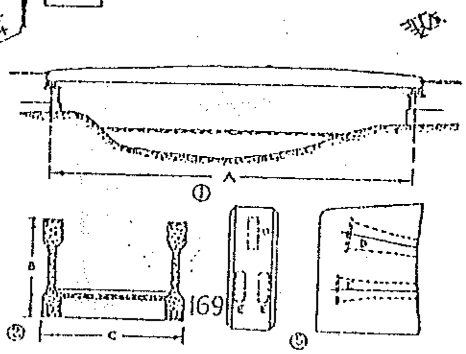
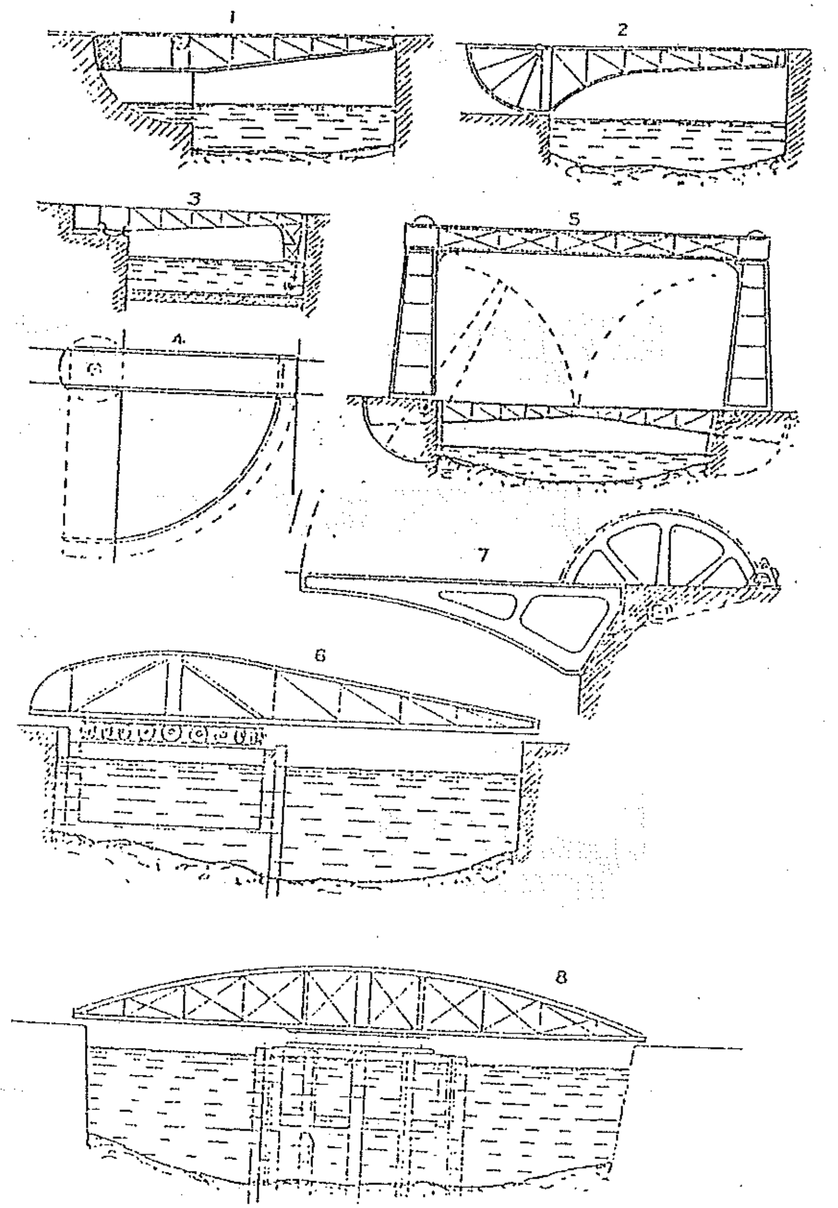


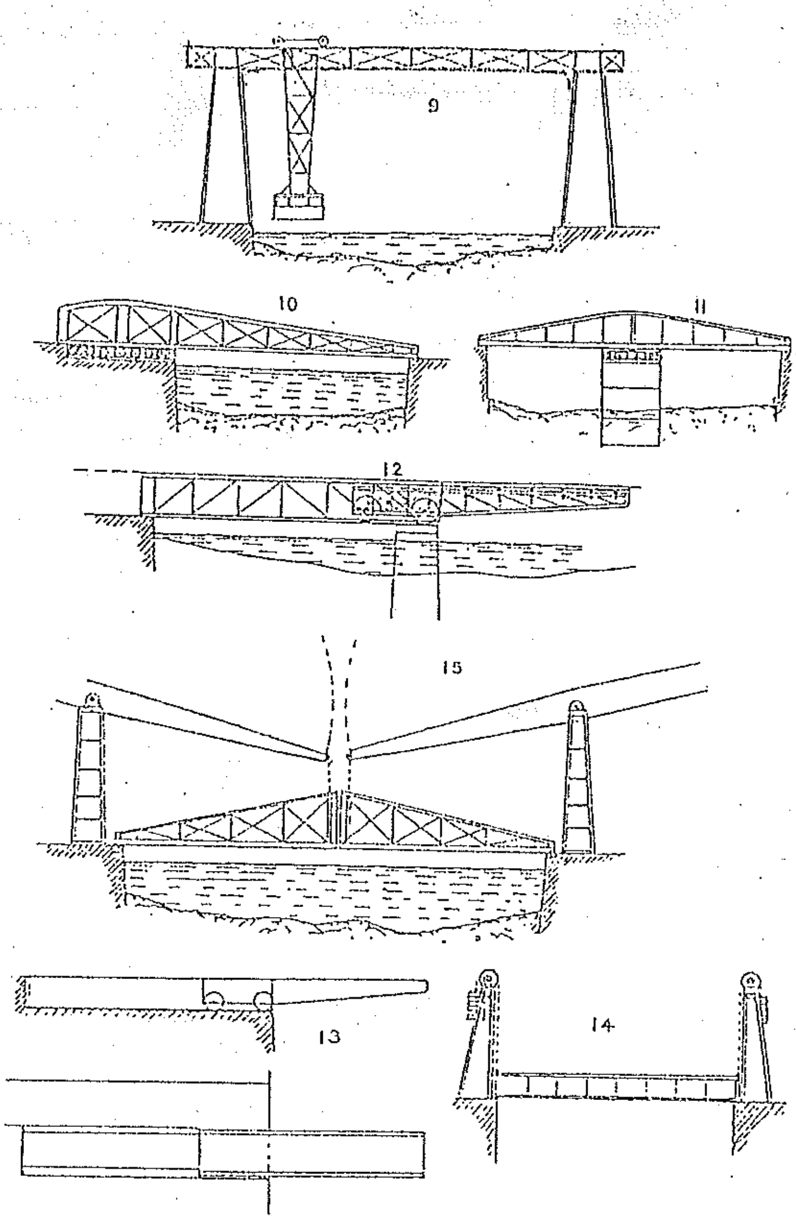
169

'omponents of standard tubular steel welded foot bridge, by Tubewrights Ltd:
(1)Portal frame; (2) Boom end; (3)Boom joint; (4)Unit portal. A=8 feet, 11 inches;
: 5 feet, 8 inches; C=3 feet, 3 inches; D=6 feet, 6 inches.
Butterley unit construction bridge. Panel length A is 10 feet. (1) Denotes panel
member; (2) Fabricated bobbin; (3) Abutment assembly; (4) Floor crossbeam.
Callender-Hamilton unit construction bridge. Standard truss components.
(1)End post vertical, (18' 5 1/8"); (2) End post horizontal; (3)End post gusset
plate; (4) Standard angle (9' 11 3/4"); (5) Angle cleat; (6) Leg plate;
(7) Side stiffener (8' 0 1/16"); (8) Leg plate; (9) Vertical (8' 6 3/16");
(10)Gusset plate; (11) Connector plate; (12) and (13) Double and single gusset
plates with welded on plates for crossbeams; (14) Connector plate; (15) Batten
plate. Crosses indicate holes for 1-inch diameter bolts.
Prestressed concrete bridge at Malheyde. Span A is 144 ft., B is 6 ft. 6 in.,
: is 9 ft. 3 in. D is one cable of 88 wires, and E, E are two cables of 88
wires of 5 mm. diameter. (1) Side elevation; (2) Cross section at mid span;
3)Cable anchorage at abutment.



OPENING BRIDGES

1 Balanced lifting bridge for short spans.
2 Rolling and lifting bridge, with balance weight for short spans.
3-4 Single swing bridge, supported on a strut frame fitted with rollers running on a curved rail on the bottom.
5 Double balanced lifting bridge, with overhead fixed bridge to be used when the lower bridge is open to the river.
6 Swing bridge on a turntable, carried by an air float.
7 Lifting bridge, with winch gear, usually balanced.
8 Double swing bridge on a central pier, giving two openings. When open it is protected from drifting vessels by dolphins or pile tenders.



OPENING BRIDGES

9 Transporter bridge.
10 Single swing bridge on a turntable.
11 Double swing bridge on central caisson pier.
12 Telescopic bridge at Queen's Ferry, Chester. The central opening span is balanced by weights and runs back on rollers under the floor of fixed side span. The central floor is hinged to swing arms and falls far enough to pass under the floor of the fixed span.
13 Rolling bridge with lateral approach.
14 Balanced lifting bridge.
15 Double-leaf lifting bridge. The lifting beams have balance weights on their inner ends.