Section G1

Design of Cast-In-Place Box Conduits

G1-1 Economy of Design

1. **Height to Width Ratio**

   Careful economic studies should be made to determine the greatest economy of the entire storm drain. As an aid to determine the most economical ratio of height to span, where it is possible to vary this ratio, a curve: Total Cost Comparison Curve for Rectangular Reinforced Concrete Sections is included (1982 ver. Manual page S-21) showing relative costs of different ratios of height to span, assuming the unit costs shown, and a common invert grade for all ratios. This curve is not directly applicable where the soffit grade is to be held. When box and pipe alternates are specified, the height of the box should, if possible, equal the internal diameter of the pipe. It will be seen that this gives a relatively economical ratio of height to span.

2. **Maximum Span**

   When the clear span of box conduits exceeds 12 feet, a cost study should be initiated to determine the advisability of using additional cell(s) with shorter spans. As an aid to determine the maximum economical span, a curve showing span vs. cost is included (1982 ver. Manual page S-22). As noted, this curve is based on the analysis of boxes of one height only. Therefore, careful judgment is required to determine if the curve is applicable.

3. **Length of Reach**

   It is considered desirable for economy of concrete and steel to change concrete thickness and reinforcing for a particular cross section at about 2-foot increments of cover when the depth of cover is varying gradually. The maximum variation in cover should not, in general, exceed 4 feet for a given section. Small changes in interior area should be avoided but, where necessary, should be made by varying the height rather than the width of the box.

G1-2 Method of Design

Box conduits shall be designed, in general, for the dead weight of the structure and vertical and horizontal earth load together with the combination of vertical live load; horizontal live load; internal water pressure; and uplift pressure, which give the greatest stresses in the various parts of the structure. Box conduits shall be checked for construction loads as discussed on page G1-6. Drawings showing loading conditions to give maximum stresses in box conduits are included (pages rev._S-17 to rev._S-20). Design sections shall be shown on the drawings and shall be identified by numerical designations.

Closed conduits shall be designed as rigid frames. Shear determination and moment distribution shall be based on centerline spans. In analysis where the members are assumed to be of constant cross-section, the stiffness of the invert slab shall be calculated using the thickness at the center of the span. Design moment shall be at the face of the support. Correction of moments from centerline to face of support shall be based on the assumption that the variation in shear between the face of the support and centerline is linear.

For design, the maximum shear shall be considered as that at the section a distance, d, (d = effective depth of member, do not include depth of haunch) from the face of support. Axial thrust shall be considered in the design of the walls but not in the top and bottom slabs. In determining the negative steel in the bottom slab, credit shall be taken for the additional 1-inch depth at the walls due to the invert drop. When nominal haunches 4 to 6 inches, are used in construction of the conduit, they shall be neglected in all phases of the design, such as in calculating shear, area of steel, and stiffness of members.

In large structures when structural considerations indicate substantial haunches (greater than 6 inches) are required, they may be considered in the design. When these haunches making an angle of 45 degrees or more, with the axis of a continuous or restrained member are built monolithic with the member and support, the face of support may be considered at a section where the combined depth of the member and the haunch is at least 1 1/2 times the thickness of the member. Design shear shall be taken at a distance, d, from this location. Design moment shall be taken at this location. No portion of the haunch shall be considered as adding to the effective depth.

When box conduits are of relatively short length, such as are used for channel crossings, and the centerline of the roadway is not normal to the centerline of the channel, a skew analysis is required. The angle of skew is defined as the angle between a line perpendicular to the roadway centerline and a line parallel to the supporting walls. The modified skew angle is the angle of skew in a place tangent to the neutral surface at any section. In slab analysis the modified skew angle is equal to the skew angle. In vertical wall analysis the modified skew angle is equal to zero. The method for skew analysis shall be as presented in Paper 2474, ASCE Transactions, Vol. 116, 1951, titled "Practical Design of Solid Barrel Reinforced Concrete Skew Structures" by Bernard L. Weiner. Under this method, the sample section for rigid frame analysis shall be taken perpendicular to the centerline of the conduit. Basic moments, thrusts, and shears are determined for this right angle section. Design moments, thrusts, and shears are obtained by multiplying the basic moments, thrusts, and shears by the square of the secant of the modified skew angle. In this method of design, the steel is placed parallel to the centerline of the roadway.

Edge beams shall be provided at the termination of all cast-in-place box conduits. Edge beams shall also be provided where traffic requirements are such that skewed construction joints will be required.

Moments induced in restrained structural members due to temperature variations or changes in moisture content of the concrete shall be considered. The temperature variation shall be assumed as a 30-degree F rise and a 40-degree F fall.

Temperature variation is not considered to be a major factor in the design of conduits with a significant depth of earth cover or in culverts of short length where the top slab is exposed, such as at street crossings, and need not be considered.

When a large portion of a structure is poured at one time, shrinkage will be realized. When the resultant stresses are high, consideration should be given to utilization of details that will prevent these stresses. For example, by leaving a small portion at the span center as a final pour, the effects of shrinkage are greatly reduced or practically eliminated.

When the structure is subject to unbalanced lateral loads, a side-sway analysis is required.

G1-3 Vertical Loads

G1-3.1 Live Load

G1-3.1.1 Highway Loading

Box conduits shall be designed for one H20-S16-44 truck per lane except where passing beneath railroad trucks.

1. For box conduits where the earth cover is 2 feet or less, wheel loads shall be distributed on the top slab in accordance with AASHTO, 3.24 and impact shall be added in accordance with the provisions of Caltrans Bridge Design Specifications 6.5.5 for culverts; i.e., 30 percent for 0 to 1-foot cover, 20 percent for more than 1-foot to 2-foot cover, and 10 percent for more than 2-foot to 3-foot cover. One standard H20-S16-44 truck per lane shall be considered on the structure and placed so as to produce maximum positive and negative moments or shear. For spans 12 feet or less, a single wheel load centered on the span is considered sufficient.

2. When the cover is over 2 feet, the wheel loads shall be considered as uniformly distributed over a square, the sides of which are equal to 1.75 times the cover.

The following tabulated pressures apply for covers of 2 to 8 feet. For covers greater than 8 feet, live load pressure shall be calculated as noted above.

TABLE OF VERTICAL LIVE LOADS

Cover "F" Feet	Wheel Load Kips	L.L. Pressure PSF
2'-1"	17.6	1,324
3	17.6	638
4	32.0	352
5	32.0	248
6	32.0	185
7	32.0	143
8	32.0	114

These values include the effect of overlapping wheel loads.

3. The width of the top slab strip used for the distribution of concentrated wheel loads shall also be used in the determination of bending moments, shears, and thrusts in the sides and bottom.

4. When the cover exceeds 8 feet and exceeds the span length, the effect of truck loads on box conduits shall be assumed to be negligible.

G1-3.1.2 Railroad Loading

Conduits passing under railroads shall be designed in accordance with the requirements of the particular railroad. In general, the minimum design loads are as follows:

Railroad	Cooper Loading
Atchison, Topeka, and Santa Fe	E 80
Southern Pacific	E 72
Union Pacific	E 72

Cooper E 65 loading may be used under industrial spur and connecting tracks under jurisdiction of Union Pacific Railroad Company.

A set of curves is included showing railroad loads at various depths of fill for Cooper’s loadings (1982 ver. Manual pages S-10 to S-16).

G1-3.2 Dead Load

G1-3.2.1 Dead Weight of Structures

The unit weight of concrete shall be taken as 150 pcf.

G1-3.2.2 Dead Weight of Overburden Soil

Earth loads shall be calculated based on a soil prism having a height H and a width equal to the box outside span, multiplied by a vertical arching factor of 1.15. The design unit weight shall ordinarily be taken as 110 pcf. This is assumed to be the actual weight of compacted backfill. When soil analysis and judgment indicate that the actual unit weight is significantly greater, the design unit weight shall be increased accordingly.

$$W = w\ H\ B_c\ (1.15)$$

Definitions

H = Height of fill measured from the top of conduit, in feet.

W = Load per foot of length of conduit, in pounds per foot.

w = The design unit weight of the fill material, in pounds per cubic foot.

B_c = Overall width of the conduit, in feet.

G1-3.3 Other External Loads

Vertical loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design of box conduits.

G1-4 Horizontal Loads

G1-4.1 Live Load

Horizontal loads due to highway and railroad loading shall be considered in the design of box conduits. Horizontal truck load shall be a trapezoidal load, in pounds per square foot, equal to 700/D, where D is equal to the depth of fill in feet, or 800 when the depth of fill is less than 1 foot. Curves are included for lateral railroad loads (1982 ver. Manual pages S-11 to S-13).

G1-4.2 Dead Load

Box conduits shall be designed for active horizontal earth pressure based on the Rankine Theory. The Rankine K shall ordinarily be taken as one third. This criteria shall be used except when a soils engineer, because of extreme conditions, recommends a different value. For extreme conditions, lateral earth pressure may exceed 100 pcf equivalent fluid pressure. Special consideration shall be given where expansive soils are encountered. When lateral loads may vary or are time dependent, it may be necessary to use a composite section based on both maximum and minimum horizontal loads.

G1-4.3 Other External Loads

Horizontal loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design of box conduits.

G1-5 Internal Water Pressure

Internal water pressure shall be calculated for the conduit flowing just full in combination with other loading conditions. An additional structural analysis shall be made if the hydraulic gradient is substantially above the top of the conduit. The hydraulic gradient shall be assumed at the maximum elevation possible. This analysis shall be made using the following loads: pressure due to the hydraulic head from the soffit of the conduit to the hydraulic gradient, the internal water assuming the conduit flowing just full, the dead weight of the structure, and vertical and horizontal earth loadings.

G1-6 Construction Loads

Structures shall be checked for loads sustained during construction to assure such construction loads do not exceed the design capacity. In particular, the loads resulting from flooded backfill on the top of the conduit combined with the dead weight of the structure shall be considered.

G1-7 Design Criteria

Design stresses and load factors shall be as modified herein for concrete boxes using the strength design procedures. Design criteria not specifically specified below shall be as specified in the 1995 Edition of the "Building Code Requirements for Structural Concrete" (ACI 318-95) published by the American Concrete Institute.

f'_c = 4,000 psi
F_y = 60,000 psi (reinforcing bars)
L.F. = 1.3 x 1.4 = 1.82 for earth and dead loads
L.F. = 1.3 x 1.67 = 2.17 for live loads
L.F. = 1.3 x 1.4 = 1.82 for thrust
L.F. = 1.3 x 1.4 = 1.82 for internal water forces
ϕ = 0.90 for flexure
ϕ = 0.85 for shear

The reinforcement ratio, rho, shall not exceed 0.375 times the balanced reinforcement ratio.

G1-8 Thickness of Members

The minimum thickness of vertical walls shall be 8 inches where two curtains of steel are used and 6 inches where one curtain is used.

The minimum thickness of top slabs shall be 6 1/2 inches.

The thickness of the invert slab shall be measured at the center of the span. The minimum thickness shall be 7 inches and shall be increased by an amount equal to the sum of the increases of the steel clearances indicated below for the top of the invert.

G1-9 Steel Clearances

Steel clearances should be shown on the project drawings from the face of the bar to the face of the concrete. Said clearances shall not be less than the following distances:

Top slab and side walls, inside and outside – 2 inches

Bottom of invert slab – 3 inches

Top of invert slab – in accordance with the following table:

Velocity – fps	Clearance – in.	Concrete Mix
< 5	3.0	560-C-4000
5 to 20	3.0	610-B-4000
20 to 40	3.5	680-B-5000
>40	Not allowed without prior LACDPW approval	

When concrete is subjected to the action of seawater or harmful groundwater, etc., all clearances shall be increased 1/2 inch. Where there is appreciable debris in the flow, the clearance on the top invert steel shall be increased 1/2 inch for velocities greater than 5 fps.

That portion of the steel clearance greater than 1 inch in the invert shall be considered as sacrificial and shall not be used in the design of the steel in the opposite face. The concrete mix shown in the above table applies to the invert only and shall be shown on the plans. Debris in the flow may require a richer concrete mix. This will be determined by the Geotechnical and Materials Engineering Division. Increased concrete strength shall not be considered in the design of the section.

G1-10 Reinforcing Steel

All lap and splice lengths shall, as a minimum, meet the requirements of the latest edition of the American Concrete Institute (ACI) 318.

In general, transverse reinforcement for single barrel boxes should consist of straight bars in the inner faces of the top and bottom slab and side walls, L-bars running from the outer face of the top slab into the outer face of the side walls and resting on the bottom construction joint and lapping with L-bars continuing into the outer face of the bottom slab. Alternate top L-bars should be cut off if possible. An optional 20 bar diameter lap shall be indicated at the base of the wall for the vertical reinforcement in the interior walls of multiple boxes and in the interior face of the exterior walls for all boxes. It is preferred that bars be spaced on a common spacing or a multiple thereof, but nonuniform spacing may be used if economy is thereby affected. In multi-barrel boxes, excessively long complexly bent bars should be avoided if possible.

G1-11 Longitudinal Reinforcement

Longitudinal reinforcement shall consist of #4 bars at 18 inches in each reinforced face of slabs and wall except where the top slab is exposed or the conduit is limited in length and serving as a channel crossing. In this and other cases where appreciable temperature variations can be anticipated, the longitudinal reinforcement area in each exposed face shall be equal to 0.001 of the cross sectional concrete area but not less than #4 bars at 18 inch centers. Longitudinal steel shall be continuous through joints.

G1-12 Distribution Steel

When the design earth cover is less than 3 feet, distribution steel shall be placed in the top slab transverse to the main reinforcing. The amount of distribution steel per foot of slab width including normal longitudinal reinforcement shall be equal to the percentage of the transverse reinforcing steel required for positive moment in the top slab as given by the formula:

$$\text{Percentage} = 100/(S)^{1/2}\text{ , Maximum 50 percent}$$

where S equals the centerline span of the slab in feet.

G1-13 Haunches

Haunches shall be placed at the junction of vertical walls and top slab. These haunches may be either 4" x 4" or 6" x 6", at the Contractor's option. These are nominal haunches and shall be incorporated in all sections. Larger haunches may be used if structural requirements so dictate.

There shall be a 1-inch drop from the base of the vertical walls to the center of the invert slab for inside widths of 20 feet or less and a 2-inch drop for widths greater than 20 feet, unless a low-flow channel in the center of the conduit is used. Low-flow channels are limited to special conditions. Their use shall be approved by the District prior to the structural design of the box conduit.

G1-14 Construction Joints

Construction joint details shall be shown on the project drawings.

Optional longitudinal construction joints at the top of the vertical exterior walls shall consist of a stepped key to take shear from exterior lateral loads and shall be 2 inches high and located in the center of the wall. Longitudinal construction joints at the bottom of vertical exterior walls shall be formed with keys 1-inch deep and one-third of the wall thickness in width centered in the wall. The bottom wall joint shall be located 4 to 12 inches, at the Contractor's option, above the top of the invert slab (see construction joint details on 1982 ver. Manual page S-23). Longitudinal construction joints at the top and bottom of vertical interior walls of multi-compartment box conduits shall be roughened joints without keys; the top joint shall be optional. Where box structures are to be jacked, longitudinal joints shall be keyed to resist jacking forces (see details on 1982 ver. Manual page S-23).

Transverse construction joints shall be formed with keys 1-inch deep and one-third the member thickness in width centered in the member. Transverse construction joints shall be spaced not more than 50 feet nor less than 10 feet and shall be in the same plane.

If the box conduit is subject to the action of seawater, the construction joint must be sealed with epoxy. Special longitudinal and transverse construction joint details will be required.

If the box conduit is designed to withstand pressure head, water stops shall be incorporated in the construction joints. Special longitudinal and transverse construction joint details will be required.

G1-15 Design Tables and Charts for Single Barrel Reinforced Concrete Box Conduits

"Design Tables for Reinforced Concrete Box Conduits" (1982 ver. Manual pages S-23 to S-36), may be used for design as long as the loading conditions shown correspond to those of the box to be designed. The standard is intended as an aid to the designer only; it should not be included in the list of Standard Drawings for a project. If concrete thicknesses are increased because of high velocity, seawater, etc., the lengths of the reinforcing bars and concrete and steel quantities indicated in the tables must also be correspondingly increased.

A structural detail of the box conduit shall be shown on the project drawings. Where several box sections are to be used, a typical box section shall be detailed on the drawings, and the data for the box sections shown in tabular form. See 1982 ver. Manual pages S-100 to S-101 for example.

G1-16 Windows

In multi-barrel boxes, windows should be placed in interior walls as required to equalize flow; however, the interval shall not exceed 500 feet. SPPWC Standard Plan 382-1 applies within the limits given on the standard. Designed windows should be 5 feet wide and as deep as possible.

G-17 Access Structures

Los Angeles County Department of Public Works (LADPW) reserves the right to require that access structures to permit the entrance of vehicles and/or equipment be provided when the conduit is equal to or greater than an 84-inch diameter pipe or box equivalent. The need for an access structure will be determined by the LADPW when the preliminary plans for a project are submitted, and the designer will be required to make the necessary changes, if any, on the final plans.

Details of a typical access structure are available as an unnumbered design aid and will be forwarded upon request.

G1-18 Box Conduits to be Jacked

G1-18.1 General

In general, jacking of box conduits should not be specified where the cover is less than 6 feet. In addition, the cover should also be at least one-half of the overall height or width, whichever is greater, when jacking under railroads.

Prior to specifying long reaches of boxes with substantial cross sectional areas to be jacked under railroad tracks, the cost of trestle construction in comparison to jacking costs should be investigated. Trestles are designed and constructed by the railroad company. Therefore, the designer shall obtain the estimated construction cost from the railroad company concerned.

In many cases, it is possible to close tracks for a short time or even a weekend. In this case, the possibility of casting the box conduit and sliding or lifting the box into place shall be investigated. This procedure is considerably less expensive than jacking.

When conduit is to be jacked under existing railroad tracks, the minimum jacking distance shall be 15 feet on each side of the centerline of the tracks measured normal to the tracks, with the exception of the Union Pacific tracks where the minimum distance shall be 10 feet. At crossings where there is a possibility the conduit could be constructed in open cut, or where the cover is less than 6 feet in jacking situations, the designer shall contact the railroad to clarify the method of construction prior to submitting the preliminary plans to the District.

When box conduit is to be jacked in place, a reinforced concrete pipe alternate shall be specified where pipe of sufficient diameter is available. Large diameter pipe is usually more economical than box conduit in such installations due to the high cost of deadmen and sliding slab requirements for box conduit.

Provisions shall be made for jacking excessively large double boxes as two single barrels side by side.

The entire reach of box conduit to be jacked must be constructed prior to the start of the jacking operation; therefore, a relatively long straight reach must be available for construction of the jacking pit.

G1-18.2 Reinforcement

The leading and trailing 5 feet of all box sections to be jacked shall have additional transverse and longitudinal reinforcement. The cross sectional area of longitudinal steel in each face of all members, except interior walls of multiple boxes, shall not be less than 0.002 times the gross concrete area for the leading and trailing 5 feet of the box conduit. This steel shall be tied. In addition, the cross sectional area of transverse steel in each face of the slabs and exterior walls of the box conduits to be jacked shall not be less than 0.002 times the gross concrete area for the leading and trailing 5 feet.

G1-18.3 Structural Notes

All drawings indicating box conduits to be jacked shall contain the following notes.

1. The Contractor shall use jacking heads or load spreading beams of such design and size as to spread the jacking force uniformly.

2. If the load spreading device or jacking head selected does not permit the required 20 bar diameter extension of the normal longitudinal steel, continuity may be maintained by doweling from the adjacent section.

3. The leading edge of the conduit shall be equipped with a jacking head securely anchored thereto. The length and details of the jacking head shall be subject to the approval of the Engineer.

4. The use of guiderails, slabs, cradles, etc., will be subject to written approval by the Engineer.

G1-19 Structural Detailing

Reinforced concrete box conduits shall be detailed in accordance with the LADPW practice; when numerous sections are required, they should be tabled. Refer to Refer 1982 ver. Manual page S-100 for an example of standard detail and form. Copies of District standard size drawing sheets are available for all District projects.

Section G2

Design of Precast Box Conduits

G2-1 GENERAL

Precast concrete box conduits are available in a wide range of sizes and thicknesses, depending on the manufacturer. Standard box sizes range from 3 feet wide by 2 feet tall to 12 feet wide by 12 feet tall. Larger sized boxes, up to 24 feet wide, may be available by special request. Local manufacturers shall be contacted for availability.

For instances in which the cover on the precast box conduit exceeds 15 feet, Department approval shall be obtained prior to start of design.

The use of precast Box Conduits shall not be permitted in instances when:

1. The ground water table is located 1 feet below the invert or higher.

2. The hydraulic grade line is located more than 4 feet above the soffit.

G2-2 Method of Design

Box conduits shall be designed, in general, for the dead weight of the structure and vertical and horizontal earth load together with the combination of vertical live load, horizontal live load, internal water pressure, and uplift pressure, which give the greatest stresses in the various parts of the structure. Box conduits shall be checked for construction loads as discussed on page G2-5. Drawings showing loading conditions to give maximum stresses in box conduits are included (pages rev._S-17 to rev._S-20). Design sections shall be shown on the drawings and shall be identified by numerical designations.

Closed conduits shall be designed as rigid frames. Shear determination and moment distribution shall be based on centerline spans. Design moment shall be that at the face of the support. Correction of moments from centerline to face of support shall be based on the assumption that the variation in shear between the face of the support and centerline is linear.

For design, the maximum shear shall be considered as that at the section a distance, d, (d = effective depth of member, do not include depth of haunch) from the face of support. Axial thrust shall be considered in the design of the walls but not in the top and bottom slabs. When nominal haunches, 4 to 6 inches, are used in manufacturing of the conduit, they shall be neglected in all phases of the design, such as in calculating shear, area of steel, and stiffness of members.

In large structures when structural considerations indicate substantial haunches (greater than 6 inches) are required, they may be considered in the design. When these haunches making an angle of 45 degrees or more with the axis of a continuous or restrained member are built monolithic with the member and support, the face of support may be considered at a section when the combined depth of the member and the haunch is at least 1 1/2 times the thickness of the member. Design shear shall be taken at a distance, d, from this location. Design moment shall be taken at this location. No portion of the haunch shall be considered as adding to the effective depth.

When box conduits are of relatively short length, such as those used for channel crossings, and the centerline of the roadway is not normal to the centerline of the channel, a skew analysis is required. The angle of skew is defined as the angle between a line perpendicular to the roadway centerline and a line parallel to the supporting walls. The modified skew angle is the angle of skew in a place tangent to the neutral surface at any section. In slab analysis, the modified skew angle is equal to the skew angle. In vertical wall analysis, the modified skew angle is equal to zero. The method for skew analysis shall be as presented in Paper 2474, ASCE Transactions, Vol. 116, 1951, titled "Practical Design of Solid Barrel Reinforced Concrete Skew Structures" by Bernard L. Weiner. Under this method, the sample section for rigid frame analysis shall be taken perpendicular to the centerline of the conduit. Basic moments, thrusts, and shears are determined for this right angle section. Design moments, thrusts, and shears are obtained by multiplying the basic moments, thrusts, and shears by the square of the secant of the modified skew angle. In this method of design, the steel is placed parallel to the centerline of the roadway.

Edge beams shall be provided where traffic requirements are such that skewed construction joints will be required.

Temperature variation is not considered to be a factor in the design of precast conduits. When the structure is subject to unbalanced lateral loads, a side-sway analysis is required.

G2-3 Vertical Loads

G2-3.1 Live Load

G2-3.1.1 Highway Loading

Box conduits shall be designed for one H20-S16-44 truck per lane except where passing beneath railroad trucks.

1. For box conduits when the earth cover is 2 feet or less, wheel loads shall be distributed on the top slab in accordance with AASHTO, 3.24 and impact shall be added in accordance with the provisions of Caltrans Bridge Design Specifications 6.5.5 for culverts; i.e., 30 percent for 0 to 1-foot cover, 20 percent for more than 1-foot to

2-foot cover, and 10 percent for more than 2-foot to 3-foot cover. One standard H20-S16-44 truck per lane shall be considered on the structure and placed so as to produce maximum positive and negative moments or shear. For spans 12 feet or less, a single wheel load centered on the span is considered sufficient.

2. When the cover is over 2 feet, the wheel loads shall be considered as uniformly distributed over a square, the sides of which are equal to 1.75 times the cover.

   The following tabulated pressures apply for covers of 2 to 8 feet. For covers greater than 8 feet, live load pressure shall be calculated as noted above.

   TABLE OF VERTICAL LIVE LOADS

Cover "F" Feet	Wheel Load Kips	L.L. Pressure PSF
2'-1"	17.6	1,324
3	17.6	638
4	32.0	352
5	32.0	248
6	32.0	185
7	32.0	143
8	32.0	114

   These values include the effect of overlapping wheel loads.

3. The width of the top slab strip used for the distribution of concentrated wheel loads shall also be used in the determination of bending moments, shears, and thrusts in the sides and bottom.

4. When the cover exceeds 8 feet and exceeds the span length, the effect of truck loads on box conduits shall be assumed to be negligible.

G2-3.1.2 Railroad Loading

Conduits passing under railroads shall be designed in accordance with the requirements of the particular railroad. In general, the minimum design loads are as follows:

Railroad	Cooper Loading
Atchison, Topeka, and Santa Fe	E 80
Southern Pacific	E 72
Union Pacific	E 72

Cooper E 65 loading may be used under industrial spur and connecting tracks under jurisdiction of Union Pacific Railroad Company.

A set of curves is included showing railroad loads at various depths of fill for Cooper loadings (1982 ver. Manual pages S-10 to S-16).

G2-3.2 Dead Load

G2-3.2.1 Dead Weight of Structures

The unit weight of concrete shall be taken as 150 pcf.

G2-3.2.2 Dead Weight of Overburden Soil

Earth loads shall be calculated based on a soil prism having a height H and a width equal to the box outside span, multiplied by a vertical arching factor of 1.15. The design unit weight shall ordinarily be taken as 110 pcf. This is assumed to be the actual weight of compacted backfill. Where soil analysis and judgment indicate that the actual unit weight is significantly greater, the design unit weight shall be increased accordingly.

$$W = w\ H\ B_c\ (1.15)$$

Definitions

H = Height of fill measured from the top of conduit, in feet.

W = Load per foot of length of conduit, in pounds per foot.

w = The design unit weight of the fill material, in pounds per cubic foot.

B_c = Overall width of the conduit, in feet.

G2-3.3 Other External Loads

Vertical loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design of box conduits.

G2-4 Horizontal Loads

G2-4.1 Live Load

Horizontal loads due to highway and railroad loading shall be considered in the design of box conduits. Horizontal truck load shall be a trapezoidal load, in pounds per square foot, equal to 700/D, where D is equal to the depth of fill in feet, or 800 when the depth of fill is less than 1 foot. Curves are included for lateral railroad loads (1982 ver. Manual pages S-11 to S-13).

G2-4.2 Dead Load

Box conduits shall be designed for active horizontal earth pressure based on the Rankine Theory. The Rankine "K" shall ordinarily be taken as one third. This criteria shall be used except where a soils engineer, because of extreme conditions, recommends a different value. For extreme conditions, lateral earth pressure may exceed 100 pcf equivalent fluid pressure. Special consideration shall be given where expansive soils are encountered. When lateral loads may vary or are time dependent, it may be necessary to use a composite section based on both maximum and minimum horizontal loads.

G2-4.3 Other External Loads

Horizontal loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design of box conduits.

G2-5 Internal Water Pressure

Internal water pressure shall be calculated for the conduit flowing just full in combination with other loading conditions. An additional structural analysis shall be made if the hydraulic gradient is substantially above the top of the conduit. The hydraulic gradient shall be assumed at the maximum elevation possible. This analysis shall be made using the following loads: pressure due to the hydraulic head from the soffit of the conduit to the hydraulic gradient, the internal water assuming the conduit flowing just full, the dead weight of the structure, and vertical and horizontal earth loadings.

G2-6 Construction Loads

Structures shall be checked for loads sustained during construction to assure such construction loads do not exceed the design capacity. In particular, the loads resulting from flooded backfill on the top of the conduit combined with the dead weight of the structure shall be considered.

G2-7 Design Criteria

Design stresses and load factors shall be as modified herein for precast concrete boxes using the strength design procedures. Design criteria not specifically specified below shall be as specified in the 1995 Edition of the "Building Code Requirements for Structural Concrete" (ACI 318-95) published by the American Concrete Institute.

f'_c = 5,000 psi
F_y = 65,000 psi (welded wire fabric)
F_y = 60,000 psi (reinforcing bars)

L.F. = 1.3 x 1.4 = 1.82 for earth and dead loads
L.F. = 1.3 x 1.67 = 2.17 for live loads
L.F. = 1.3 x 1.4 = 1.82 for thrust
L.F. = 1.3 x 1.4 = 1.82 for internal water forces
ϕ = 0.95 for flexure
ϕ = 0.90 for shear

The reinforcement ratio, rho, shall not exceed 0.375 times the balanced reinforcement ratio.

G2-8 Thickness of Members

The minimum thickness of the walls, soffit, and invert shall be span (inches)/12 or 6 inches, whichever is greater.

G2-9 Steel Clearances

Steel clearances should be shown on the project drawings from the face of the bar to the face of the concrete. Said clearances shall not be less than 1 inch except as set forth below.

Top of soffit slab - when depth of fill is less than 2 feet, clear concrete cover shall be 2 inches.

Top of invert slab – in accordance with the following table:

Velocity – fps	Clearance – in.	Min 28-Day Concrete Strength
< 5	1.5	5,000 psi
5 to 20	2.0	5,000 psi
20 to 40	2.5	5,000 psi
>40	Not allowed without prior LACDPW approval	

When concrete is subjected to the action of seawater or harmful ground water etc., all clearances shall be increased 1/2 inch. When there is appreciable debris in the flow, the clearance on the top invert steel shall be increased 1/2 inch.

That portion of the steel clearance greater than 1 inch in the invert shall be considered as sacrificial and shall not be used in the design of the steel in the opposite face.

G2-10 Reinforcing Steel

The positioning of the steel reinforcing assemblies shall be shown in ASTM C1433 and shall meet the requirements of ASTM A 615 or ASTM A 497. Distribution steel shall comply with ASTM A 82, ASTM A 185, ASTM A 496, ASTM A 497, or ASTM A 615. All lap and splice lengths shall, as a minimum, meet the requirements of the latest edition of ASTM C1433 and the American Concrete Institute (ACI) 318.

G2-11 Distribution Steel

When the design earth cover is less than 3 feet, distribution steel shall be placed in the top slab transverse to the main reinforcing. The amount of distribution steel per foot of slab width including normal longitudinal reinforcement shall be equal to the percentage of the transverse reinforcing steel required for positive moment in the top slab as given by the formula:

$$\text{Percentage} = 100/(S)^{1/2}\text{, Maximum 50 percent}$$

where S equals the centerline span of the slab in feet.

G2-12 Haunches

Haunches shall be placed at the junction of the vertical walls and top and bottom slabs. These haunches, equal to or greater than the wall thickness, may be included in the design procedure. These are nominal haunches and shall be incorporated in all sections. Larger haunches may be used if structural requirements so dictate.

G2-13 Design Tables and Charts for Single Barrel Precast Reinforced Concrete Box Conduits

Design Tables for Single Barrel Precast Reinforced Concrete Boxes are located at the end of this section and may be used for design as long as the loading conditions shown on page rev._S-17 correspond to those of the box to be designed. The standard is intended as an aid to the designer only.

If haunches with other dimensions than that shown in the Tables are used, a special reinforcement design for the actual dimensions shall be completed. In lieu of performing a special design for the specific case where the actual haunch dimensions are larger than that indicated in the Tables and vertical and horizontal haunch dimensions are equal, the As1 steel area shall be increased 1 percent for every 5 percent increase in the haunch dimension over that specified in the Tables.

G2-14 Box conduits to be Jacked

G2-14.1 General

In general, jacking of box conduits should not be specified where the cover is less than 6 feet. In addition, the cover should also be at least one half of the overall height or width, whichever is greater, when jacking under railroads.

Prior to specifying long reaches of boxes with substantial cross sectional areas to be jacked under railroad tracks, the cost of trestle construction in comparison to jacking costs should be investigated. Trestles are designed and constructed by the railroad company. Therefore, the designer shall obtain the estimated construction cost from the railroad company concerned.

In many cases, it is possible to close tracks for a short time or even a weekend. In this case, the possibility of sliding or lifting the box into place shall be investigated.

When conduit is to be jacked under existing railroad tracks, the minimum jacking distance shall be 15 feet on each side of the centerline of the tracks measured normal to the tracks, with the exception of the Union Pacific tracks where the minimum distance shall be 10 feet. At crossings where there is a possibility the conduit could be constructed in open cut, or where the cover is less than 6 feet in jacking situations, the designer shall contact the railroad to clarify the method of construction prior to submitting the preliminary plans to the District.

When box conduit is to be jacked in place, a reinforced concrete pipe alternate shall be specified where pipe of sufficient diameter is available. Large diameter pipe may be more economical than box conduit in such installations due to the high cost of deadmen and sliding slab requirements for box conduit.

Provisions shall be made for jacking excessively large double boxes as two single barrels side by side.

G2-14.2 Reinforcement

The leading and trailing 18 inches (minimum) of all box sections to be jacked shall have additional transverse and longitudinal reinforcement. The cross sectional area of longitudinal steel in each face of all members, except interior walls of multiple boxes, shall not be less than 0.002 times the gross concrete area for the leading and trailing 18 inches (minimum) of the box conduit. This steel shall be tied. In addition, the cross sectional area of transverse steel in each face of the slabs and exterior walls of the box conduits to be jacked shall not be less than 0.002 times the gross concrete area for the leading and trailing 18 inches (minimum).

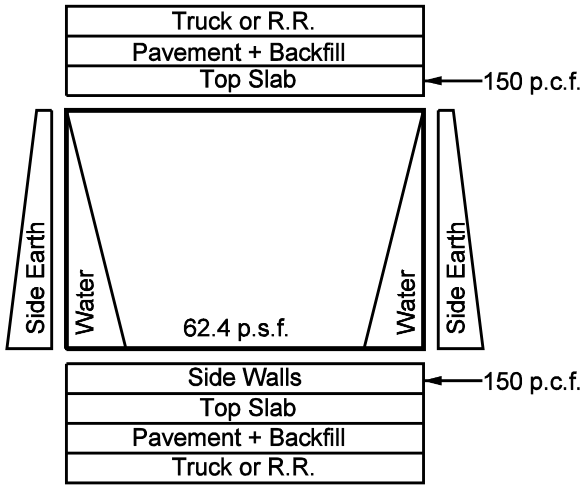
G2-14.3 Structural Notes

All drawings indicating box conduits to be jacked shall contain the following notes.

1. The Contractor shall use jacking heads or load spreading beams of such design and size as to spread the jacking force uniformly.

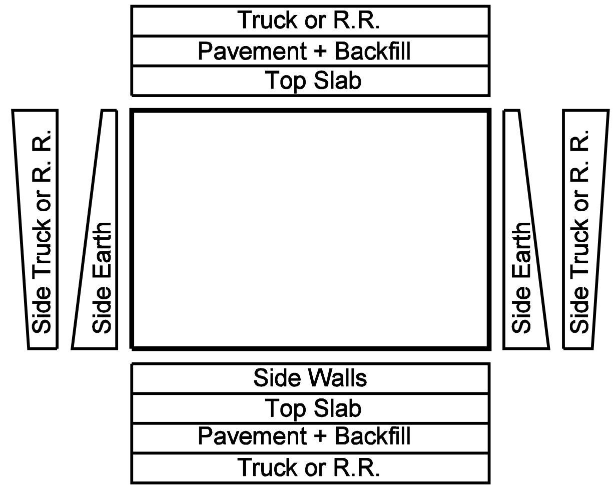
2. The leading edge of the conduit shall be equipped with a jacking head securely anchored thereto. The length and details of the jacking head shall be subject to the approval of the Engineer.

3. The use of guiderails, slabs, cradles, etc., when used, will be subject to written approval by the Engineer.



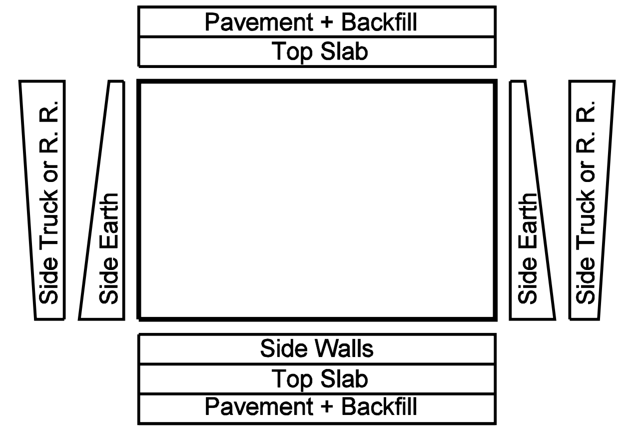
LOAD COMBO 1

MAX. (+) MOMENT, TOP AND BOTTOM SLABS
MAX. (-) MOMENT, SIDE WALLS



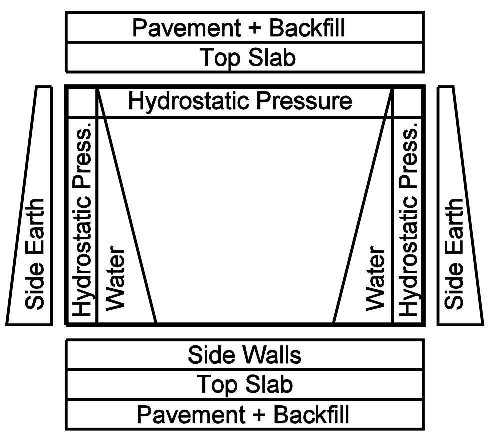
LOAD COMBO 2

MAX. (-) MOMENT CORNERS
MAX. SHEARS



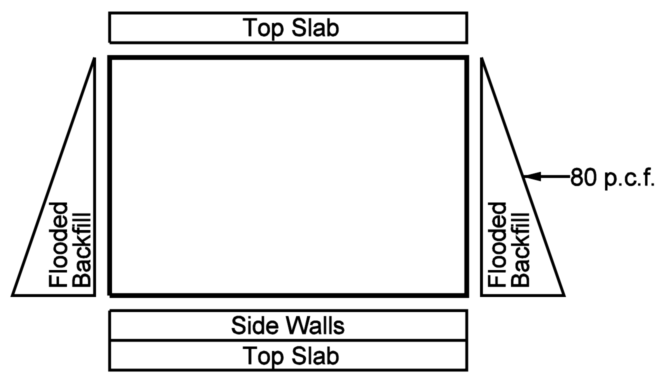
LOAD COMBO 3

MAX. (+) MOMENT, SIDE WALLS



LOAD COMBO 4

MAX. (-) MOMENT TOP SLAB
AND SIDE WALLS WITH
HYDROSTATIC HEAD



LOAD COMBO 5

MAX. (+) MOMENT, SIDE WALLS

Special Conditions - All boxes

1. 0'-2' Cover, treat as bridge
2. Box under hydrostatic head

Note

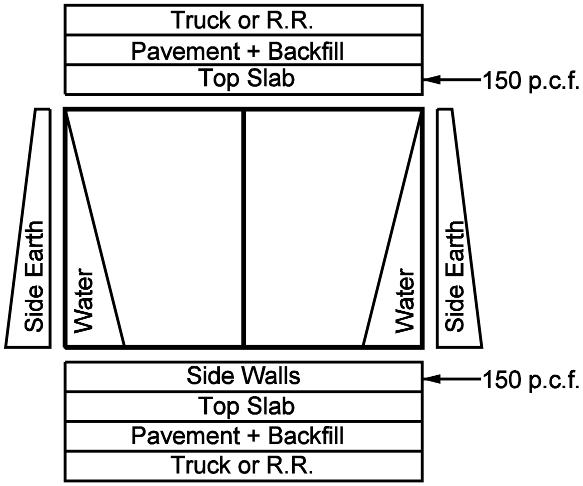
(+) Indicates tension on inside of box
(-) Indicates tension on outside of box

STANDARD LOADING CONDITIONS FOR DESIGN OF SINGLE BARREL BOX CONDUIT

Los Angeles County Department of Public Works

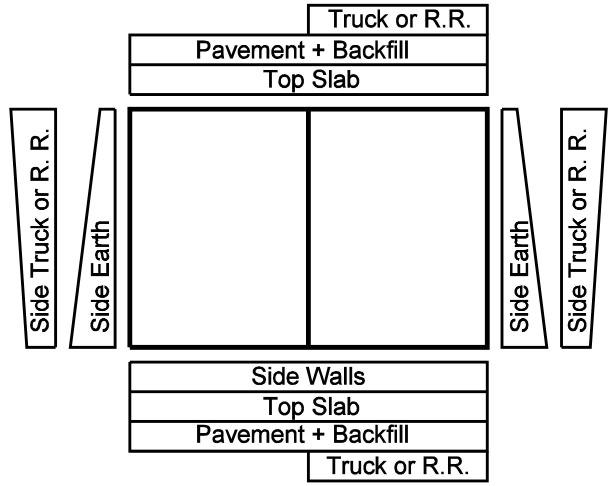
rev._S-17

Rev. 11/07



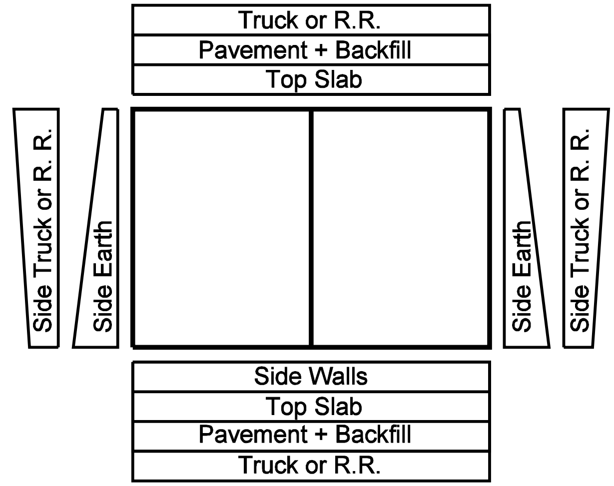
LOAD COMBO 1

MAX. (-) MOMENT, TOP AND BOTTOM SLABS AT CENTER WALL



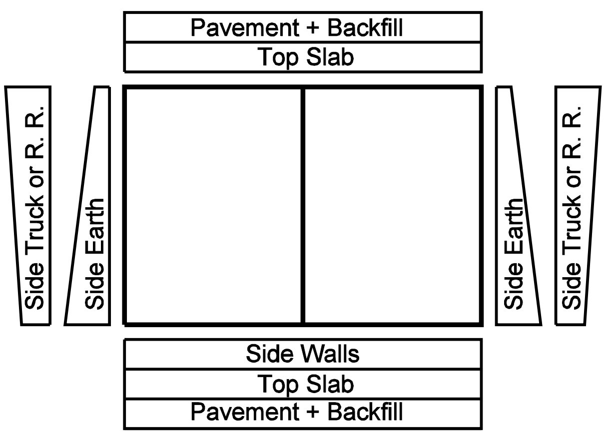
LOAD COMBO 2

MAX. (+) MOMENT, TOP AND BOTTOM SLABS
MAX.(-) MOMENT, SIDE WALLS



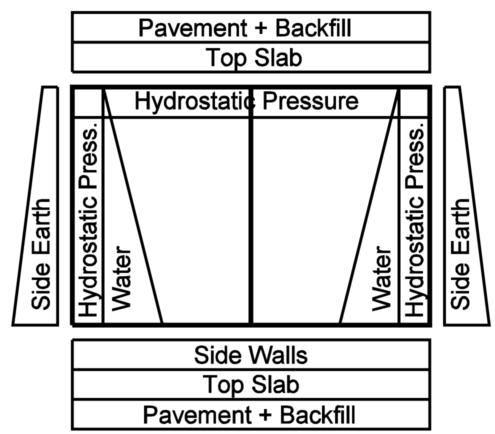
LOAD COMBO 3

MAX. (-) MOMENT, CORNERS
MAX SHEARS



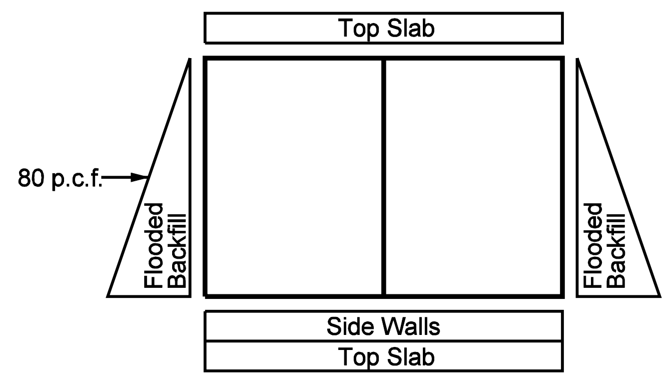
LOAD COMBO 4

MAX. (+) MOMENT, SIDE WALLS



LOAD COMBO 5

MAX. (-) MOMENT TOP SLAB AND SIDE WALLS. MAX TENSION CENTER WALL, WHEN HYDRO. HEAD EXISTS



LOAD COMBO 6

MAX. (+) MOMENT, SIDE WALLS

Special Conditions - All boxes

1. 0'-2' Cover, treat as bridge
2. Box under hydrostatic head

Note

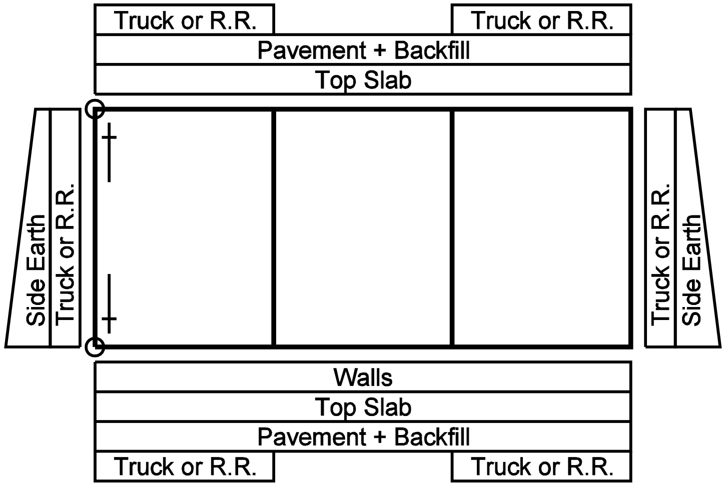
(+) Indicates tension on inside of box
(-) Indicates tension on outside of box

STANDARD LOADING CONDITIONS FOR DESIGN OF DOUBLE BARREL BOX CONDUIT

Los Angeles County Department of Public Works

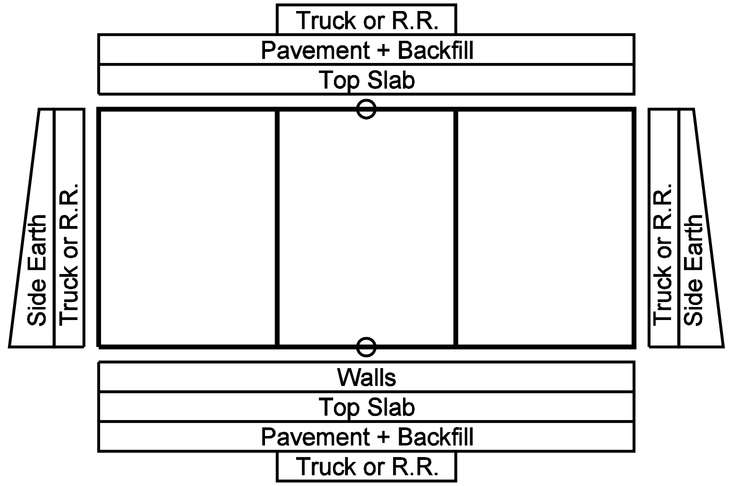
Rev. 11/07

rev._S-18



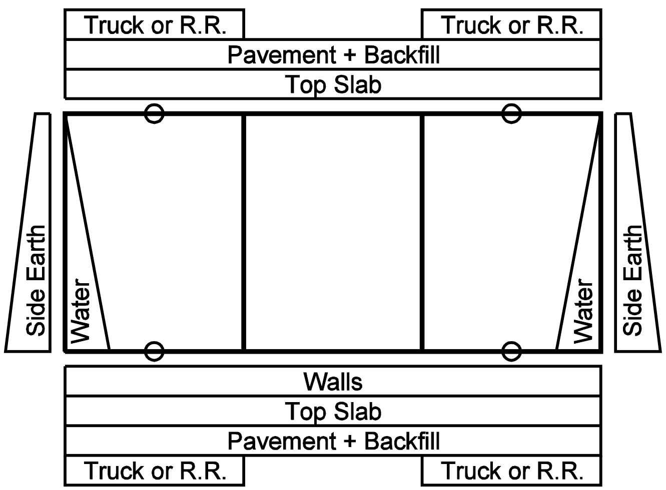
LOAD COMBO 1

MAX. (-) MOMENT, CORNERS
MAX. SHEAR, CORNERS



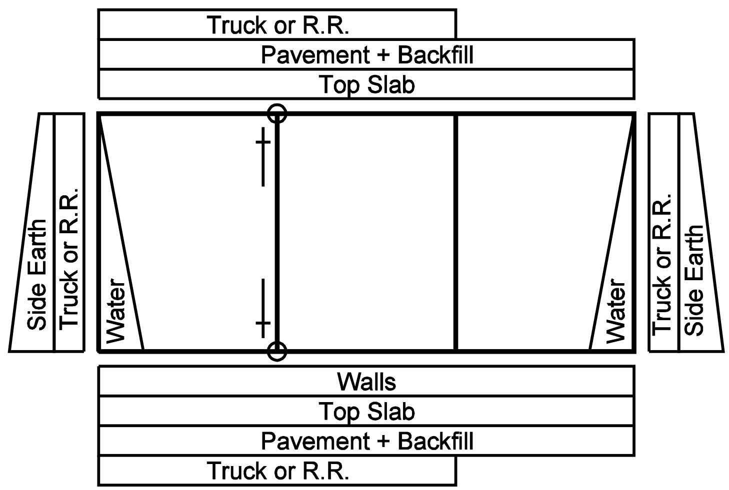
LOAD COMBO 2

MAX. (+) MOMENT CENTER
BARREL TOP AND BOTTOM SLABS



LOAD COMBO 3

MAX. (+) MOMENT OUTSIDE
BARRELS TOP AND BOTTOM SLABS



LOAD COMBO 4

MAX. (-) MOMENT AT CENTERWALL
MAX. SHEAR AT CENTERWALL

Special Conditions - All boxes

1. 0'-2' Cover, treat as bridge
2. Box under hydrostatic head

Notes

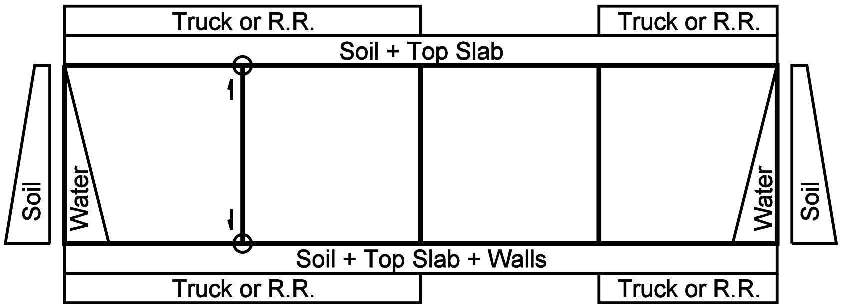
1. o Point of Critical Moment
   † Point of Critical Shear
2. (+) Indicates tension on inside of box
   (-) Indicates tension on outside of box

STANDARD LOADING CONDITIONS FOR DESIGN OF TRIPLE BARREL BOX CONDUIT

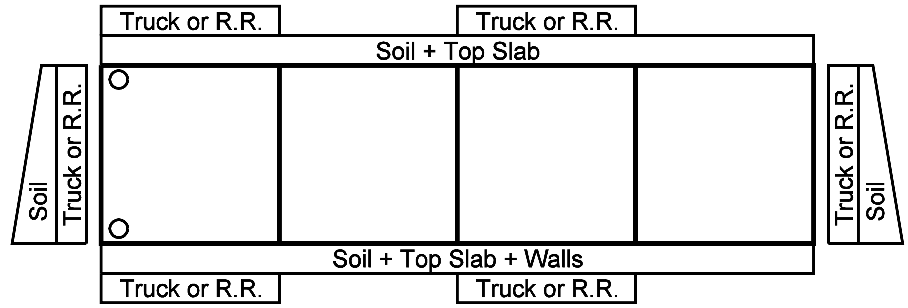
Los Angeles County Department of Public Works

rev._S-19

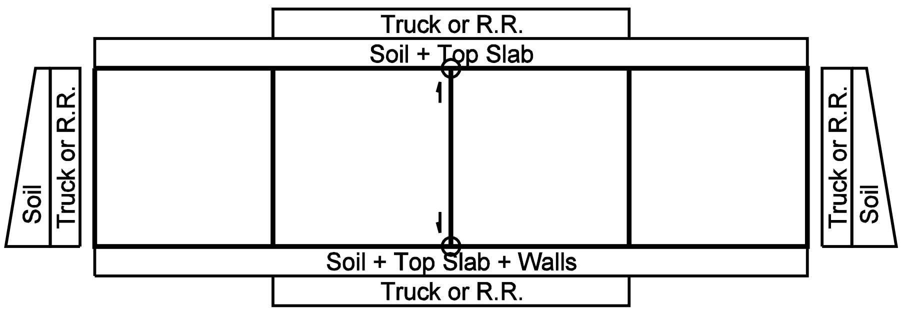
Rev. 11/07



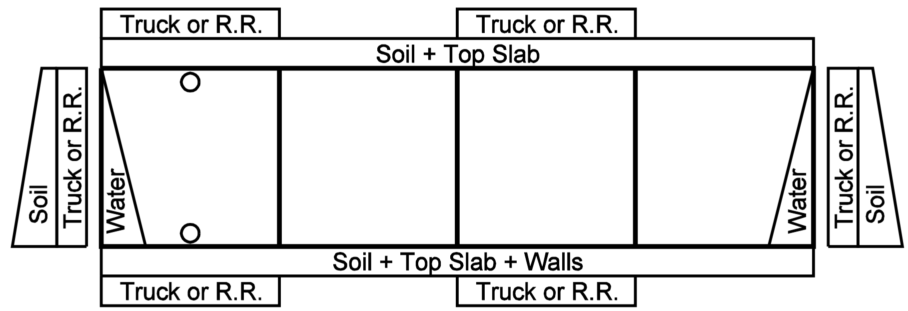
LOAD COMBO 1



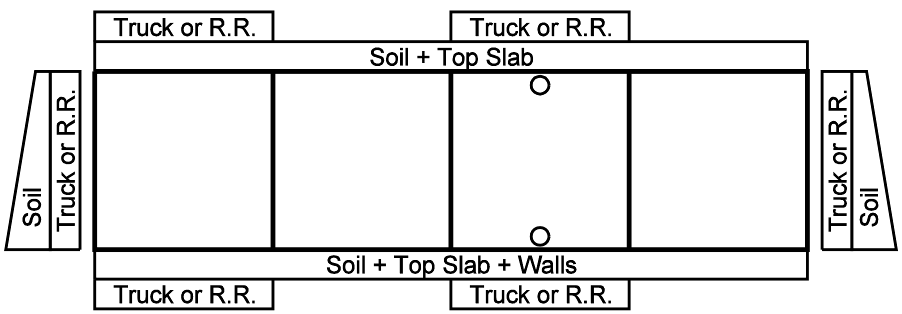
LOAD COMBO 2



LOAD COMBO 3



LOAD COMBO 4



LOAD COMBO 5

Special Conditions - All boxes

1. 0'-2' Cover, treat as bridge
2. Box under hydrostatic head

Notes

- o Point of Critical Moment
- † Point of Critical Shear

STANDARD LOADING CONDITIONS
FOR DESIGN OF FOUR
BARREL BOX CONDUIT

Los Angeles County Department of Public Works

Rev. 11/07

rev._S-20