

Culvert Load Rating and Live Load Through Fill

Culverts are buried structures. The soil around them is part of the load path: it carries the earth load, spreads truck wheel loads before they reach the top slab, and pushes on the walls. That is why rating a culvert is different from rating a girder bridge. This course covers soil-structure interaction, the AASHTO LRFD live-load distribution through fill developed in NCHRP Project 15-29 (NCHRP Report 647), the dynamic load allowance for buried structures, live load surcharge, analysis models for reinforced concrete box culverts from simple 2D frames to 3D soil-structure models, and what field load testing has shown. It draws on NCHRP Report 647 Appendix C (proposed specification revisions, April 2009) and the Louisiana DOTD RC Box Culverts Testing and Rating Statewide Final Report (SDR Engineering Consultants, July 2020), which summarizes AASHTO MBE Article 6A.5.12, AASHTO LRFD provisions and NCHRP 15-54 findings. All worked numbers are labeled illustrative.

Learning objectives

- Explain soil-structure interaction
- Distribute live load through fill
- Rate concrete box culverts
- Know when load testing helps

Why culverts are rated differently

A girder bridge carries truck loads directly on its deck. A buried culvert carries them through soil. The Louisiana DOTD report (2020) describes the load path: the wheel load passes into the pavement and spreads slightly, then spreads further through the fill until it reaches the top slab. There it is distributed both in the span direction and along the culvert length. The walls carry it down to the bottom slab, which spreads it into the foundation soil.

The same report gives the key reason culvert ratings are often disputed. It describes culverts as behaving differently from structures resting on the ground, because a composite system develops between the culvert members and the surrounding soil, and both contribute to structural behavior. It attributes the satisfactory field performance of many older culverts that rate poorly on paper to:

- actual concrete strength, typically greater than the as-built design strength;
- culvert-soil interaction;
- construction quality;
- conservatism in the AASHTO procedures used to distribute live load through fill.

Rating a culvert therefore involves three linked questions: how much load reaches the structure, how the structure is modeled, and how much capacity it has. This course takes them in that order. It assumes familiarity with the LRFR rating factor from [BR-L01](#) and builds on the culvert types and condition issues in [BR-CU01 Culvert Inspection](#).

History of the provisions

According to the Louisiana DOTD report, the 2013 Interim Revisions to the second edition of the AASHTO Manual for Bridge Evaluation (MBE) introduced Article 6A.5.12 for rating reinforced concrete box culverts by LRFR only, with further live load guidance in the 2014 interim. The report notes that the 2013 revisions stated that the lane load is not applied when

rating the top slabs of concrete box culverts. The authors observe that this departs from the Standard Specifications and LRFD design practice and was introduced without stated justification. Separately, NCHRP Project 15-29 (NCHRP Report 647, 2010) produced the live-load-through-fill provisions that the Louisiana report says were introduced in the 2013 LRFD interim and adopted in the LRFD 7th Edition. NCHRP Project 15-54 later proposed modifications to the culvert load rating specifications. An AASHTO release note for BrDR 7.6 lists changes based on that project, discussed later in this course.

Earth loads: EV, EH and ES

The Louisiana DOTD report groups the effect of fill into three loads:

- **EV, vertical earth pressure:** the weight of soil above the culvert. The report notes that AASHTO LRFD accounts for soil-structure interaction in computing EV and relates it to the installation method.
- **EH, lateral earth pressure:** pressure on the exterior walls, increasing linearly with depth. AASHTO LRFD assumes an at-rest linear distribution using a lateral coefficient K_o based on the friction angle of granular fill.
- **ES, uniform surcharge:** additional lateral pressure from the continuous roadway fill, applied uniformly over the culvert height.

The report states that, for live load rating, the lateral pressure should be reduced by 50 percent with a load factor of 1.0. The reason is that lateral earth pressure on a box culvert's walls produces top slab moments opposite to those from vertical loads, so overestimating it can be unconservative for the top slab midspan.

Arching and nonlinear lateral pressure

The report reviews a Texas Transportation Institute study of an instrumented 8 ft by 44 ft box culvert under up to 8 ft of fill, loaded by a test vehicle with a 48 kip tandem rear axle. Measured lateral pressures were nonlinear because of soil arching. In the report's comparison for a 3-cell 8 ft by 8 ft culvert under 8 ft of fill with a 31 degree friction angle, the AASHTO linear at-rest distribution gave a wall mid-height moment 13 percent greater than the nonlinear distribution that accounts for arching.

The practical message is that earth load assumptions are not neutral. They affect the rating in both directions depending on the member and location, and the conservative choice for one section is not conservative for another.

Live load through fill: the basic rule

NCHRP 15-29 Appendix C sets out the proposed LRFD Article 3.6.1.2.6, which became the basis of the current approach.

Shallow fill

Under the proposed wording, where the fill is less than 2.0 ft over flat-top, three-sided or long-span concrete arch culverts, the effect of the fill on live load distribution is neglected. Live load is then distributed to the top slab using the deck-slab provisions (Article 4.6.2.10, which the proposal cites). For round culverts the threshold is 1.0 ft, and round culverts with less than 1.0 ft of fill are to be analyzed with more comprehensive methods.

The Louisiana DOTD report quotes the shallow-fill strip widths from LRFD Article 4.6.2.10:

- $E = 96 + 1.44S$, the equivalent width perpendicular to the span in inches, with S the clear span in feet;
- $E_{\text{span}} = l_t + \text{LLDF} \times H$, the equivalent length parallel to the span, with l_t the tire contact length.

Deeper fill

Where the fill is deeper than these limits, the proposal distributes each wheel load uniformly over a rectangle. The rectangle starts at the tire contact area (20 in wide by 10 in long) and grows with depth by a live load distribution factor (LLDF) multiplied by the fill depth. The commentary says this resembles the 60 degree rule in soil mechanics texts. The tire contact area is set at the surface, the surface pressure is based on the wheel load without dynamic allowance, and the dynamic load allowance is then added to the pressure on the projected area. The design lane load is applied where appropriate, and multiple presence factors apply.

The LLDF values

Proposed Table 3.6.1.2.6-1 gives:

Culvert type	Transverse	Longitudinal
Reinforced concrete pipe	1.15 for diameter ≤ 2 ft; 1.75 for diameter ≥ 8 ft; interpolated between	Same as transverse, plus 0.06 times the span
All others	1.15	1.15, plus 0.06 times the span

NCHRP 15-29 Appendix C Table 1 summarizes the changes for all types: the LLDF no longer depends on soil type, fill under 1 ft is ignored for round culverts and under 2 ft for flat-top and 3-sided culverts, rectangular area equations were added, and a 0.06D_i term was added for each culvert type. Older provisions used 1.15 for select granular backfill and 1.0 for other soils. The Appendix C proposal shows that older wording struck through.

When live load can be neglected

The Appendix C wording keeps the rule that for single-span culverts the effects of live load may be neglected where the fill is more than 8.0 ft and exceeds the span length. For multiple-span culverts, live load may be neglected where the fill exceeds the distance between the faces of the end walls. As discussed later, an AASHTOWare release note reports that NCHRP 15-54-based changes replace the 8 ft rule with a pressure-ratio test.

The rectangular area equations

NCHRP 15-29 Appendix C proposes equations for the size of the loaded rectangle at the top of the culvert. The variables are:

- H = depth of fill over the culvert (ft)
- w_t = tire patch width, 20 in; l_t = tire patch length, 10 in
- s_w = wheel spacing, 6 ft
- D_i = inside diameter or clear span of the culvert (in)
- LLDF from the table above

Wheel interaction depth

The two wheels of an axle spread independently until their patches meet. The proposed interaction depth is:

$H_{int} = [s_w - w_t/12 - 0.06D_i/12] / LLDF$

Patch width (across the axle)

- For $H < H_{\text{int}}$: $w_w = w_t/12 + \text{LLDF} \cdot H + 0.06D_i/12$ (each wheel separately)
- For $H \geq H_{\text{int}}$: $w_w = w_t/12 + s_w + \text{LLDF} \cdot H + 0.06D_i/12$ (both wheels combined)

Patch length

$l_w = l_t/12 + \text{LLDF} \cdot H$, and the area is $A_{LL} = l_w \times w_w$.

Where areas from several wheels overlap, the total load is spread uniformly over the combined area. The Louisiana DOTD report shows the same approach applied in the direction of traffic, with an axle interaction depth $H_{\text{int-p}} = (s_a - l_t/12)/\text{LLDF}$, where s_a is the axle spacing. Below that depth the patch length is $l_t/12 + \text{LLDF} \cdot H$, and at or beyond it the length becomes $l_t/12 + s_a + \text{LLDF} \cdot H$.

The orientation question

In these equations the $0.06D_i$ term widens the patch in one direction to reflect the span of the culvert. Software and agency practice differ on how the patch is oriented relative to the culvert span when traffic crosses at a skew. This course does not resolve that question. Check the edition and commentary your agency uses.

Illustrative live load pressure calculation

The following example is **illustrative**. The inputs are assumed and it is simplified to a single axle. It is not a complete rating and does not include lane load, multiple presence or tandem checks.

Assumed data (illustrative)

- Single-cell reinforced concrete box, clear span 10 ft, so $D_i = 120$ in
- Fill depth $H = 4.0$ ft
- $\text{LLDF} = 1.15$
- One 32 kip axle, two 16 kip wheels at 6 ft spacing

Step 1: interaction depth

$H_{\text{int}} = [6 - 20/12 - 0.06(120)/12]/1.15 = [6 - 1.667 - 0.600]/1.15 = 3.733/1.15 \approx 3.25$ ft. Since $H = 4.0$ ft ≥ 3.25 ft, the two wheel patches overlap.

Step 2: patch width

$$w_w = 1.667 + 6.0 + 1.15(4.0) + 0.600 = 12.87 \text{ ft.}$$

Step 3: patch length (single axle)

$$l_w = 10/12 + 1.15(4.0) = 0.833 + 4.60 = 5.43 \text{ ft.}$$

Step 4: area

$$A_{LL} = 12.87 \times 5.43 \approx 69.9 \text{ ft}^2.$$

Step 5: dynamic load allowance

Using the equation quoted in the Louisiana DOTD report, $IM = 33(1.0 - 0.125D_E) \geq 0$, so $IM = 33(1 - 0.5) = 16.5$ percent.

Step 6: pressure on the top slab

$p = 32 \times 1.165 / 69.9 \approx 0.53$ ksf (before multiple presence and load factors).

Compare: shallower fill (illustrative)

At $H = 2.5$ ft, $H < H_{int}$, so each wheel spreads separately. $w_w = 1.667 + 1.15(2.5) + 0.600 = 5.14$ ft, $l_w = 0.833 + 2.875 = 3.71$ ft, area ≈ 19.1 ft² per wheel. $IM = 33(1 - 0.3125) \approx 22.7$ percent. Pressure $\approx 16 \times 1.227 / 19.1 \approx 1.03$ ksf, roughly twice the 4 ft value. This shows why shallow-fill culverts are so sensitive to live load, and why the Louisiana study found shallow-fill ratings governed by top slab positive moment in its pinned-connection analyses.

Compare: deep fill (illustrative)

At 8 ft of cover, IM reaches zero. The patch is now large, about $1.667 + 6 + 9.2 + 0.6 \approx 17.5$ ft wide, and the pressure from a single axle is a small fraction of the earth load. That is the physical basis for the provisions allowing live load to be neglected at large depth.

Dynamic load allowance and live load surcharge

Dynamic load allowance for buried structures

The Louisiana DOTD report quotes the AASHTO LRFD dynamic load allowance for culverts:

$$IM = 33(1.0 - 0.125D_E) \geq 0 \text{ percent}$$

Here D_E is the minimum depth of earth cover above the structure in feet. IM is 33 percent for direct contact (no cover) and decreases linearly to zero at 8 ft. NCHRP 15-29 Appendix C commentary states that the tire contact area dimensions are based on the 33 percent allowance at zero depth, and the allowance is added to the pressure on the projected area.

Live load surcharge (LS)

When a truck approaches a culvert, its wheels push on the soil beside the exterior walls. The Louisiana DOTD report explains that AASHTO LRFD and the MBE have represented this with a uniform lateral surcharge on the exterior walls, $\Delta p = k_o \gamma_s h_{eq}$, with h_{eq} an equivalent height of soil for vehicular load.

Citing NCHRP 15-54, the report criticizes this approach on several grounds:

- The same equation is used for retaining walls and box culverts despite their different behavior.
- An approaching wheel increases overturning on a wall but produces only small lateral pressure on a culvert.
- Field tests show the pressure decreases rapidly with depth rather than staying uniform.
- The maximum lateral pressure occurs at the top slab level, so it passes as thrust through the top slab rather than bending the walls.

NCHRP 15-54, as summarized, recommends using the ASTM C1577 equation, $p_{lat}(H) = 700/H < 800$ psf, for culverts with less than 2.0 ft of fill over the top slab, and applying no lateral live load surcharge for fill heights greater than 2 ft. The report

notes these findings were submitted as a ballot item for possible inclusion in the MBE and LRFD.

The AASHTOWare BrDR 7.6 release note describes software changes based on NCHRP 15-54:

- removing the provision to neglect live load where fill is more than 8 ft;
- allowing live load to be neglected when the factored live load vertical pressure at the culvert surface is less than 10 percent of the sum of factored vertical earth plus factored vertical live load pressure;
- replacing the lateral live load surcharge (LS) with an approaching wheel (AW) load;
- revising the equivalent strip width for live load distribution.

These changes show that culvert rating provisions have shifted noticeably within the past decade. A rating file from 2014 and one from today may rest on different rules for the same structure.

Analysis models for box culverts

The Louisiana DOTD report reviews four modeling levels for reinforced concrete box culverts.

1. 2D frame-element model

A unit-width strip of the cross-section is modeled with linear-elastic frame elements for the top slab, walls and bottom slab. Typically soil-structure interaction is ignored, and the frame rests on a pin and a roller with loads applied to both slabs. The report says this is acceptable and conservative for design, but that for rating such over-conservatism is less desirable, especially for special heavy loads. It describes the model as the least sophisticated for rating and says it most often leads to unrealistically low ratings (citing Okeil et al. 2018).

A variation replaces the supports with vertical compression springs under the bottom slab. It still ignores soil-structure interaction but allows differential settlement and a more natural bottom slab reaction. The report cites Okeil et al. (2018) finding that springs changed governing forces by at most 4.0 percent and deflections by 4.3 percent, and other studies concluding that springs have a negligible effect on the rating factor.

2. 3D shell-element model

The whole culvert length is modeled with shell elements, capturing continuity and two-way bending of the top slab, typically with spring supports. The report calls this a robust tool for design and an appropriate method for rating. It takes more time but gives more realistic, repeatable results. Okeil et al. (2018) also used rigid corner elements and calibrated rotational springs at wall-slab joints to represent partial moment release where sections crack.

3. 2D soil-structure model

The soil is modeled with finite elements and the culvert with frame elements, so self-weights and live load distribute through the soil automatically. The report notes Petersen et al. (2010) found linear-elastic soil models inadequate for buried structures, and cites Lawson et al. (2010) finding, across 100 TxDOT culverts, that this approach raises ratings compared with spring models.

4. 3D soil-structure model

This is the most sophisticated and most reliable approach, but it is computationally intensive. The report recommends using 2D soil-structure models to select a soil constitutive model before moving to 3D.

Correction factors from 3D to 2D

The Louisiana project built 120 3D finite element models with matching 2D frames and defined correction factors as the ratio of 3D to 2D live load moments at the critical top slab sections. The factors differed for positive and negative moment, varied with culvert size and fill height, were roughly constant below 2 ft of fill, and increased linearly from 2 to 4 ft and from 4 to 9 ft. The resulting formulas apply only for fill heights of 1 to 9 ft and cell spans of 5 to 12 ft. In the project's ratings, the factors applied ranged from about 0.68 to 0.88 for the culverts listed. These are Louisiana-specific results, not general AASHTO values.

The rating factor applied to culverts

Culverts use the same LRFR idea as bridges: the rating factor is the capacity left after permanent load effects, divided by the factored live load effect. In general form:

$$RF = (C - \Sigma \gamma_{perm} \cdot (\text{permanent load effects})) / (\gamma_{LL} \cdot (LL + IM))$$

The exact MBE article, load factors and condition and system factors should be taken from the edition your agency uses (see this course's flag). For culverts, two things make the formula harder to apply than for girders.

Earth loads can help or hurt

Vertical earth load (EV) adds to top slab positive moment. Lateral earth pressure (EH and ES) on the walls produces top slab corner moments that oppose it. A maximum load factor on lateral pressure is conservative for the walls and corners but unconservative for the top slab midspan. This is why, as the Louisiana DOTD report summarizes, lateral pressure is reduced 50 percent with a load factor of 1.0 for live load rating of the top slab case, and why rating software checks maximum and minimum combinations.

Where ratings are controlled

The Louisiana study's results illustrate how the critical section changes with fill and with modeling assumptions:

- **Pinned wall-slab connections** (a conservative assumption for older Louisiana culverts whose plans show no corner continuity reinforcement and walls reinforced on the inner face only): shallow-fill culverts were controlled by top slab positive moment in the exterior cells, with rating factors of 0.515 and 0.572 for 1939 and 1949 culverts with light reinforcement (#4 at 7 in in slabs). Medium fills (2 to 6 ft) were mostly controlled by positive moment at exterior wall mid-height. Deep fills (6 to 8 ft) gave rating factors of zero at exterior wall mid-height because the earth pressure moments alone exceeded nominal capacity. Ten of 12 culverts rated below 1.0.
- **Moment connections** (full framing): with one exception, all culverts were controlled by the bottom section of the exterior wall, with rating factors from 1.060 to 1.729. The study judged full framing reasonable because unfactored forces at the unreinforced corner sections stayed below the cracking moment, so capacity could be limited to cracking moment there.

The same culverts, the same loads and the same reinforcement moved from mostly failing to all passing on the strength of one modeling assumption. That is why a culvert rating needs a clear statement of its assumptions and why reviewers should look at the model before the rating factor.

Legal loads and posting

Once rating factors are computed for legal vehicles, the posting decisions in [BR-L03 Load Posting](#) apply to culverts that meet the bridge definition. Because short spans respond to single axles and tandems rather than gross vehicle weight, the Louisiana report notes AASHTO's recognition that bridge-based calibration may not suit culvert response.

What field load tests have shown

The Louisiana DOTD project load tested 12 cast-in-place box culverts built between 1939 and 1971 from Louisiana standard plans, chosen to cover different fill heights, sizes, numbers of cells and soil zones. Each was instrumented with displacement and strain sensors. A three-axle dump truck of about 66 kips gross (front axle about 18 kips), described as roughly equal to the AASHTO design truck, was driven along four load paths and stopped at four positions per path, set to maximize top slab effects. A dynamic test was also run to look at live load surcharge.

Findings

- Measured top slab strains were much lower than predicted: finite element models using the as-built concrete strength (3.5 ksi for class A concrete) and AASHTO live load distribution predicted strains 2 to 3 times larger than measured, for all test culverts.
- The authors attribute the gap to actual concrete strength above the as-built value, conservatism in the AASHTO distribution through fill, and soil-structure interaction.
- The report also cites Okeil et al. (2018), whose eight earlier load tests of Louisiana culverts showed strains below cracking levels with the exterior cell midspan moment controlling, and Lawson et al. (2010), whose tests on three TxDOT culverts gave much higher ratings at critical sections than any modeling technique.

Recommended procedure from the study

The report recommends moment-connection 2D models with: 3D/2D correction factors applied as live load scale factors; clear spans and heights after removing rigid zones; $K_o = 0.50$ with the AASHTO linear at-rest distribution; LS per LRFD Article 3.11.6.4; virtual corner reinforcement for full framing. It then lists optional refinements: arching-adjusted lateral pressure, NCHRP 15-54 surcharge recommendations, and an LLDF of 1.75 for fill under 2 ft. For that last item it argues that the 1.15 factor is extremely conservative, noting that ASCE 15-98 (SIDD) allows 1.75 and a Florida study found about 2.0.

These are recommendations for Louisiana DOTD's culvert population, not national requirements. They show the levers available when a culvert that has performed well for decades rates poorly. Load testing as a general tool is covered in [BR-L06 Load Testing](#).

When load testing helps

Drawing on the evidence above, testing is most useful when:

- a structure in good condition rates poorly under a simple model;
- its behavior depends on uncertain corner continuity or soil interaction;
- it is part of a large family of similar culverts built from the same standard plans, so results can inform many ratings.

It helps least when the culvert shows significant deterioration, because a diagnostic test at service load does not establish the capacity of corroded steel or delaminated concrete.

Pipes and flexible culverts

NCHRP 15-29 Appendix C also proposed changes for pipes and flexible culverts.

Reinforced concrete pipe

Besides the LLDF varying from 1.15 to 1.75 with diameter, the proposal set the live load bedding factor for indirect design of reinforced concrete pipe to 2.2 for all fill heights and diameters, replacing a table in which the factor fell to as low as 1.1 for large pipes under shallow fill. If the earth load bedding factor is less than the live load bedding factor, the earth load factor is used instead.

Corrugated metal pipe

The proposed thrust equation for metal pipe splits dead and live load. The live load part is $P_{LL} \times \min(S, l_t + LLDF \cdot H) \times F_1 / 2$, with a factor F_1 that depends on span, tire length and fill depth. Its lower limit is $\max(15/(S/12), 1)$ for corrugated metal pipe, and a separate form applies to long-span structures. The intent, consistent with the report's 3D analyses, is that live load thrust in a pipe depends on how much of the spread load actually falls on the pipe.

Thermoplastic pipe

A similar thrust form was proposed for plastic pipe. The commentary notes a 1.3 factor on water load to cover uncertainty in groundwater level, which the engineer may vary based on site knowledge.

Rating implications

For flexible pipes, ratings are typically governed by wall thrust, buckling or seam strength rather than by bending, and the condition findings from [BR-CU01](#) (shape, deflection, seam cracking, section loss) feed directly into those capacities. This course does not cover flexible culvert capacity checks in detail.

Inspection data that ratings need

This section is the course's synthesis for inspectors and raters. A culvert rating is only as good as its inputs, and several of those inputs come from the field.

Fill depth

Fill depth changes the distribution area, the dynamic allowance and whether live load matters at all. The Louisiana report notes that as-built plans or in-situ measurements can establish fill. Overlays, regrading and widening change the fill depth that plans show. Measure the cover at the shallowest point over the culvert, including pavement, and record where traffic lanes and wheel paths fall relative to the cells.

Geometry and reinforcement

Measure the clear span, clear height, slab and wall thicknesses, haunches and number of cells, and identify the standard plan revision if possible. The Louisiana study shows how much the reinforcement details of specific plan revisions control ratings.

Condition

- Top slab: transverse cracking at midspan, efflorescence, spalls with exposed steel. These matter for positive moment capacity.
- Walls: horizontal cracking at mid-height or near the bottom, bulging and leaning. These matter for the sections that controlled many Louisiana ratings.
- Corners: cracking at wall-slab joints, which suggests a loss of continuity and supports a pinned assumption.
- Bottom slab and foundation: undermining and differential settlement. See [BR-CU02 Culvert Hydraulics](#) for the scour and sediment processes behind them.
- Section loss of reinforcement, for which the rater needs measured remaining areas. See [BR-L04 Rating Deteriorated Members](#).

Pavement

The Louisiana report reviews a Kansas DOT study that found lower top slab pressure under rigid pavement than under flexible pavement of the same thickness. Pavement type is usually ignored in rating, but recording it costs nothing.

A checklist for raters (synthesis)

- Which LRFD and MBE edition and interims are you using, and do they include NCHRP 15-54-based revisions?
- What fill depth governs, and is live load neglected? On what basis: the 8 ft rule, the span rule or the 10 percent pressure test?
- Which LLDF, and why?
- Pinned or fixed corners, and why?
- How were lateral pressures and live load surcharge treated?
- Do the condition findings support the capacities assumed?

For inventory reporting of culverts, see [BR-S01 SNBI Overview](#).

Where the NCHRP 15-29 provisions came from

NCHRP Project 15-29, published as NCHRP Report 647 (2010), studied live load distribution to buried structures. Its Appendix C presents the specification changes the research team proposed. The Appendix C commentary states that the simplified distribution equations were developed from three-dimensional analyses of 830 culverts. Those analyses covered a range of culvert types, spans and fill depths, and the proposed equations were fitted so that the simple rectangular-area method would produce live load effects comparable to the 3D results.

Several features of the proposal follow from that origin:

- **No soil-type dependence.** The earlier specifications used a larger LLDF for select granular backfill than for other soils. The 3D work led the team to remove that distinction, so a single LLDF of 1.15 applies to most types.
- **The 0.06D_i term.** A wider culvert collects load from a wider area of soil. Instead of an elaborate 3D analysis, the proposal adds a width increment proportional to the inside span.
- **Larger LLDF for big concrete pipe.** The table raises the factor from 1.15 to 1.75 as reinforced concrete pipe diameter grows from 2 ft to 8 ft.
- **Shallow fill thresholds.** Below about 1 ft (round) or 2 ft (flat-top), the soil is too thin to spread load reliably, so the proposal treats the structure like a deck slab or calls for more comprehensive analysis.

It is worth reading the proposal and commentary in full if you rate many culverts, because rating software implements these equations with choices about orientation, overlap and lane load that the text alone does not fix.

Illustrative shallow-fill strip calculation

The following example is **illustrative**, using assumed data. It shows the shallow-fill strip method quoted in the Louisiana DOTD report from LRFD Article 4.6.2.10.

Assumed data (illustrative)

- Box culvert with clear span $S = 8$ ft
- Fill (including pavement) $H = 1.5$ ft, less than 2 ft, so the shallow-fill provisions apply
- Tire contact length $l_t = 10$ in
- LLDF = 1.15

Equivalent width perpendicular to the span

$$E = 96 + 1.44S = 96 + 1.44(8) = 107.5 \text{ in} \approx 8.96 \text{ ft.}$$

Equivalent length parallel to the span

$$E_{\text{span}} = l_t + \text{LLDF} \times H = 10 \text{ in} + 1.15 \times 18 \text{ in} = 30.7 \text{ in} \approx 2.56 \text{ ft.}$$

Dynamic allowance (illustrative)

$$\text{IM} = 33(1 - 0.125 \times 1.5) = 33 \times 0.8125 \approx 26.8 \text{ percent.}$$

Interpretation

A 16 kip wheel is spread over a strip about 9 ft wide perpendicular to the span and applied as a patch about 2.6 ft long along the span. Per foot of strip width, the wheel gives $16 \times 1.268 / 8.96 \approx 2.26$ kips per foot, applied over 2.56 ft of the top slab span, or about 0.88 ksf over that patch. These values are before load and multiple presence factors.

Compare this with the 2.5 ft fill example earlier (about 1.03 ksf under one wheel's own patch). The two methods do not produce a smooth transition at 2 ft. That is one reason the Louisiana report discusses alternatives at shallow fill, including a larger LLDF.

Illustrative earth load magnitudes

To see why earth loads dominate deep-fill ratings, consider an **illustrative** single-cell box with assumed data: 8 ft clear height, 6 ft of fill, soil unit weight 120 pcf and $K_o = 0.50$ (the value the Louisiana study used).

- Vertical earth pressure on the top slab, before any installation or soil-structure interaction factor: $6 \times 120 = 720$ psf.
- Lateral earth pressure at the top of the wall: $0.50 \times 720 = 360$ psf.
- Lateral earth pressure at the bottom of the wall, about 14 ft below the surface (ignoring slab thicknesses for simplicity): $0.50 \times 120 \times 14 = 840$ psf.

Compare these with the illustrative live load pressure of about 0.53 ksf (530 psf) at 4 ft of cover, which will be smaller still at 6 ft. At this depth the earth pressures on the walls are comparable to or larger than the live load pressure on the top slab, and

they act on members that in older designs may have had light reinforcement on only one face.

This is the mechanism behind the Louisiana result that deep-fill culverts rated zero under a pinned-corner model: the wall mid-height moment from earth pressure alone exceeded nominal capacity. When the corners were modeled as continuous, the wall mid-height moment dropped because the end moments carried part of it, and the controlling section moved to the bottom of the exterior wall.

A rating of zero for a culvert that has carried traffic for 60 years without distress is a strong signal that the model, not the structure, needs a second look.

Multiple cells, tandems and lane load

Multi-cell culverts

Many highway culverts have two to four cells. The Louisiana correction factors differ for exterior and interior cells and for positive and negative moment, reflecting continuity over interior walls. In a 2D frame, the live load patch must be moved across the full width to find the worst position for each section. A patch straddling an interior wall usually maximizes negative moment there, while a patch centered in an exterior cell maximizes that cell's positive moment.

Tandem and axle groups

The rectangular area method spreads each wheel by depth. At modest depths the patches from adjacent axles in a tandem merge, using the axle interaction depth discussed earlier. For short-span culverts, closely spaced heavy axles of legal and specialized hauling vehicles can govern over the HL-93 truck. The vehicle set and posting logic should follow [BR-L03](#) and [BR-D02](#).

Lane load

Under the proposed NCHRP 15-29 wording, the design lane load is applied where appropriate. According to the Louisiana DOTD report, however, the 2013 MBE interim revisions stated that lane load is not applied when rating the top slabs of concrete box culverts. Where the edition you use has this instruction, follow it for rating. Be aware that design and rating can therefore differ on the same structure.

Multiple presence

The NCHRP 15-29 proposal states that multiple presence factors apply. For culverts wide enough to carry two lanes over a cell, check both one-lane and multi-lane cases with their respective factors.

Common rating pitfalls

The following list is a synthesis of the sources' findings, framed as practical checks.

1. **Using plan fill instead of actual fill.** Overlays and regrading change the cover, and the shallow-fill cases are the most sensitive. Measure the cover.
2. **Assuming pinned corners without checking.** Old standard plans may lack corner continuity steel. The Louisiana study shows that the decision between pinned and continuous corners can move ratings from zero to above 1.0. Justify the choice, for example by checking whether service moments at unreinforced sections stay below cracking, as the Louisiana study did.

3. **Applying maximum lateral pressure everywhere.** Lateral pressure helps the top slab midspan and hurts the walls and corners. Use the minimum and maximum combinations the specification calls for.
4. **Uniform live load surcharge on deep-fill walls.** NCHRP 15-54 found the uniform LS model unrealistic for culverts. Check whether your edition has replaced it with the approaching-wheel load.
5. **Using the 8 ft rule after it has been replaced.** The BrDR 7.6 note describes a pressure-ratio test replacing it. A culvert with 8 ft of cover and a long span may need live load considered under one rule and not the other.
6. **Ignoring the as-built concrete strength gap.** The Louisiana report attributes part of the test-versus-model gap to actual concrete strength above the design value. Coring to establish in-place strength is a legitimate refinement where justified.
7. **Ignoring deterioration.** Refinements that raise a rating assume the sections are intact. Section loss, delamination at the top slab soffit and undermining of the bottom slab reduce capacity and can change the controlling section.

Putting it together: a rating workflow

This is a suggested sequence, synthesizing the sources. Agency procedures govern.

1. **Collect.** Gather plans or field measurements of geometry, reinforcement (by plan revision or GPR or exploratory openings), fill depth at the shallowest point, pavement type, and condition, including section loss.
2. **Choose the specification edition.** Record the LRFD and MBE editions and interims and whether NCHRP 15-54-based changes are included.
3. **Screen live load.** Decide whether live load can be neglected under the applicable rule.
4. **Distribute live load.** Use the shallow-fill strip method or the rectangular-area method, with IM based on cover.
5. **Apply earth loads.** Include EV, EH, ES and the live load surcharge or approaching-wheel model as the edition requires, with minimum and maximum combinations.
6. **Model.** Start with a 2D frame. Document the corner assumption, supports and member lengths.
7. **Rate.** Compute rating factors at all critical sections for design, legal and permit vehicles as required.
8. **Refine if needed.** If the culvert is in good condition and rates low, consider in-place material strength, continuity justification, 3D or soil-structure modeling, correction factors where a validated agency procedure exists, and diagnostic load testing ([BR-L06](#)).
9. **Decide.** Post, monitor or rehabilitate, and record the basis so the next rater can follow it.

Because the provisions have changed several times since 2013, the record of which rules were used matters as much as the rating factor itself.

Glossary of culvert rating terms

- **LLDF:** live load distribution factor, the rate at which the loaded area grows with fill depth (1.15 for most types under the NCHRP 15-29 proposal).
- **H_{int} :** the wheel interaction depth, below which the patches from the two wheels of an axle overlap and are combined.
- **H_{int-p} :** the corresponding axle interaction depth in the direction of travel.
- **D_i :** inside diameter or clear span, used in the $0.06D_i$ width term.
- **D_E :** minimum depth of earth cover used in the dynamic load allowance equation.
- **EV, EH, ES:** vertical earth pressure, horizontal earth pressure and earth surcharge.
- **LS:** live load surcharge, the lateral pressure on walls from vehicles near the culvert.

- **AW**: approaching wheel load, the NCHRP 15-54-based replacement for LS described in the AASHTOWare BrDR 7.6 note.
- **K_o**: at-rest lateral earth pressure coefficient (0.50 in the Louisiana study).
- **3D/2D correction factor**: the ratio of live load moment from a 3D model to that from a 2D frame. In the Louisiana study it was used to scale 2D live load effects; the formulas are valid only for 1–9 ft fill and 5–12 ft cell spans.
- **Pinned versus moment connection**: whether the wall-slab joints are modeled as transferring moment. This is a dominant assumption for old culverts without corner steel.
- **Diagnostic load test**: a test at known service loads that measures response in order to calibrate a model. It is not a proof of ultimate capacity.

Keep this glossary next to the rating file. Most disagreements over culvert ratings reduce to differences in one of these items.

Key takeaways

- Culverts work with the surrounding soil; field performance of older culverts often exceeds what simple ratings predict.
- Earth loads EV, EH and ES each affect ratings; lateral pressure is reduced 50 percent with a load factor of 1.0 for live load rating per the summarized MBE practice.
- Under the NCHRP 15-29 provisions, fill under 2 ft (flat-top) or 1 ft (round) is ignored for distribution and the deck-slab strip method applies.
- Deeper fill: tire patch 20 in × 10 in grows by LLDF × H (LLDF 1.15 for most types, up to 1.75 for large RC pipe) plus 0.06Di across the span.
- Dynamic load allowance falls from 33 percent at zero cover to zero at 8 ft: $IM = 33(1.0 - 0.125DE)$.
- 2D frame models are simple but conservative; 3D and soil-structure models and load tests often show more capacity.
- NCHRP 15-54 work replaced the uniform live load surcharge and the 8 ft live load cutoff in newer provisions; confirm your edition.

References

1. AASHTO, The Manual for Bridge Evaluation, 3rd Edition, 2018 (with interim revisions)
2. AASHTO, LRFD Bridge Design Specifications, 9th Edition, 2020
3. NCHRP Report 647, Recommended Design Specifications for Live Load Distribution to Buried Structures, 2010
4. NCHRP Project 15-29, Appendix C, Proposed Revisions to AASHTO Specifications, CNA Consulting Engineers and Simpson Gumpertz & Heger, April 2009 (online appendix to NCHRP Report 647).
5. SDR Engineering Consultants, RC Box Culverts Testing and Rating Statewide, Final Report, State Project No. H.009859.5, Louisiana DOTD, July 15, 2020.
6. AASHTOWare, Bridge Design and Rating (BrDR) 7.6 New Features and Enhancements (culvert highlights citing NCHRP Project 15-54).

Study text only; the final quiz is taken online. Verify all references against the edition your agency has adopted.