limitstate ring

a rapid analysis tool for masonry arch bridges

Application Note - Practical assessment of UK highway masonry arch bridges

(Based on recommendations given in UK Highways Agency Standard BD21/01)

This application note discusses how the output from LimitState:RING can be used to calculate the maximum gross vehicle weight which can safely be applied to a typical highway masonry arch bridge according to standard UK practice.

1. Critical loading case

- HA type loading is not applicable to masonry arch bridges.
- The majority of masonry arch bridges have short to medium spans (i.e. approx. 5m or less) and for such bridges a single axle loading case will generally be critical. For medium to long span bridges multiple axle loading cases may be critical and for very long span bridges foreseeable live loadings will anyway typically be small compared with the dead weight of the structure.

2. Effective bridge width

When using two-dimensional analysis software (e.g. LimitState:RING) appropriate assumptions are required in order to determine the effective bridge width (w). For cases in which there are no longitudinal cracks in evidence in the barrel of the bridge being considered and when centrifugal effects are absent, then the effective width may be calculated as the minimum of all the expressions given in Table 1 (prepared in accordance with BD21/01).

N^{o.}	Loading Configuration	Effective width (w) for an Axle Loading	Notes
1	Single wheel	[1.5+h]×2	
2*	Single axle	1.8+(1.5+h)	Wheels at 1.8m spacing (see BD21 para. 6/23)
3	Single axle	Bridge width	
4	Two axles side by side	[0.7+2×1.8+(1.5+h)]/2	Wheels at 1.8m spacing; 0.7m between axles (see BD21 para. 6/23)
5	Two axles side by side	[Bridge width]/2	

* This case is assumed when an 'auto-computed' effective bridge width is specified in LimitState:RING

Table 1 - Expressions to be used to calculate the effective width of an axle loading

Where h is the depth of fill at the position of the applied load. Note that the minimum notional lane width is 2.5m (i.e. the carriageway must be at least 5m wide to accommodate two lanes/vehicles).

N.B. if centrifugal effects are present you should always consider a single wheel case in addition to other cases.

3. Centrifugal effects and 'axle lift off'

- If the horizontal road alignment is curved (i.e. there is a bend in the road over the structure) then centrifugal effects should be considered as more load will act on one wheel than the other. The equivalent increased static load is obtained by applying a centrifugal effect factor, F_A:

  $$F_A = 1 + (0.20v^2/r)$$

  Where v = vehicle speed in m/s and r = radius of curvature of carriageway in m. Centrifugal effects may mean that a single wheel load is the most critical loading condition.

  The centrifugal effect factor can be applied in LimitState:RING by modifying the effective bridge width used in calculations:

  $$w_{mod} = w/F_A$$

- If the vertical road alignment is sharply curved (e.g. a hump back bridge) then one should consider the possibility of 'axle lift off'. Here the load from an axle that has lost contact with the carriageway surface should potentially be distributed among the remaining axles in a bogie (see e.g. BD21/01 para. 6.23 and BA16/97 Annex B3 for guidance). This can be modelled in LimitState:RING by creation of a modified loading vehicle with redistributed axle loads.

4. Partial Factors of Safety and Condition Factor

Based on the values given in BD21/01 (para. 6.20), the following partial safety factors are suggested for use with loading vehicles in LimitState:RING:

Partial factor	Value	Notes
γ_{f3}	1.0	LimitState:RING validated against test results therefore γ_{f3} = 1.0 implicitly assumed.
$\gamma_{f,dyn}$	1.8	Generally applied only to the most heavily loaded axle.
$\gamma_{f,l}$	1.9	Applied to all axles, including the dynamic axle.

Table 2 - Partial factors of safety

Applying the partial safety factors in Table 2 means that all axle live loads are subject to scaling by 1.9 and one (generally that with the greatest magnitude) also incorporates an impact factor of 1.8, bringing the total partial safety factor for this axle to 3.42 (c.f. γ_{fL} = 3.4 from BD21/01).

A condition factor (between 0.0 and 1.0) should be applied if the structure under consideration has a defect which affects carrying capacity but which cannot be taken account of in the current analysis. In general it is better to try to model defects directly. Defects such as ring separation, low strength masonry and the effect longitudinal cracks have on the ability of a given bridge to distribute the load transversely can all be accounted for directly when using LimitState:RING in conjunction with suitable effective width calculations.

5. Gross Vehicle weight

The following table can be used to calculate the maximum gross vehicle weight that can safely be carried for a given computed LimitState:RING 'adequacy factor', assuming that i) an 11.5T single axle load vehicle has been used (often the most critical) and also ii) an appropriate effective bridge width and all relevant partial factors have been entered into LimitState:RING.

LimitState:RING Adequacy Factor on 11.5T Single Axle*	Corresponding Single Axle Loading* (kN)	Maximum Gross Vehicle Weight (T)
1.0	113	40/44
0.78	88	12.5
0.61	69	10
0.47	54	7.5
0.18	20	3

*Assuming that the correct effective width and all relevant partial factors have been entered into LimitState:RING

Table 3 - Gross vehicle weights

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