TECH-LINE

BGFMA
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Technical Update of the Bridge Grid Flooring Manufacturers Association

Tech-Line, Issue #18, July 2018

LRFR Design Load Rating of Grid Reinforced Concrete and Exodermic® Decks

Load rating is the determination of the safe live load carrying capacity of a highway structure. It is usually expressed as a Rating Factor (RF) or in terms of tonnage for a particular vehicle. Rating frequency may vary by owner but is usually performed in the design stage, initial inventory inspection, when there is a change of live loading or dead load on the structure, or if there is a physical change in any structural member of the bridge. The Manual for Bridge Evaluation, Third Edition, 2018 (MBE) implies that decks should be rated as a main load carrying component of the superstructure. Some owners may overlook this requirement for conventional reinforced concrete decks but require rating of grid reinforced concrete and Exodermic® decks for new construction.

Design load rating in accordance with the MBE and AASHTO LRFD Bridge Design Specifications, Eighth Edition, 2017 (LRFD) is relatively straightforward and simplified by using the BGFMA V3.1 design program. The rating equation is stated as:

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)} \qquad \text{(6A.4.2.1-1 MBE)}$$

where:

$$C = \varphi_c \varphi_s \varphi R_n \qquad \text{(6A.4.2.1-2 MBE)}$$

φ_c is the Condition Factor and can be taken as 1.00 in accordance with Table 6A.4.2.3-1 MBE for new decks.
φ_s is the System Factor for flexural effects and can be taken as 1.00 in accordance with Table 6A.4.2.4-1 MBE since grid reinforced concrete and Exodermic® decks are highly redundant systems.
φR_n is the Nominal Resistance of the deck and calculated as the Moment Capacity of the deck and shown as the smallest value of $\emptyset M_n$ in the BGFMA design program.
For a newly constructed deck, $\varphi_c \varphi_s \geq 0.85$ (6A.4.2.1-3 MBE) is satisfied.

$(\gamma_{DC})(DC)$ is the permanent dead load moment effect of the deck self-weight and shown as M_{DC} in the BGFMA design program, where $\gamma_{DC} = 1.25$ in accordance with Table 6A.4.2.2-1 MBE and Table 3.4.1-2 LRFD. The weight of the deck is calculated on a separate sheet in the design program.

$(\gamma_{DW})(DW)$ is the permanent dead load moment effect of any additional deck wearing surface and shown as M_{DW} in the BGFMA design program, where $\gamma_{DW} = 1.50$ in accordance with Table 6A.4.2.2-1 MBE and Table 3.4.1-2 LRFD. This factor is only to be applied if the wearing surface is present. The weight of this wearing surface is a separate input in the design program.

$(\gamma_P)(P)$ represents the moment effect from any permanent loads other than dead loads. This is rare and shall be considered equal to zero hereafter in this article.

$\gamma_{LL} = 1.75$ for Inventory rating and $\gamma_{LL} = 1.35$ for Operating rating in accordance with Table 6A.4.3.2.2-1 MBE. $IM = 1.33$ in accordance with Table 3.6.2.1-1 LRFD. LL is the live load moment effect calculated from equations 4.6.2.1.8-1 through 4.6.2.1.8-4 LRFD and shown as M_{LL} in the BGFMA design program where the Live Load Moment Multiplier (LLMM) is set equal to 1.00. It is important to note that the live load moment effects specified in 4.6.2.1.8 LRFD equations already include $\gamma_{LL} = 1.75$ and $IM = 1.33$. Therefore, when rating the deck using the above equation, substitute the following values for the given variables: (Continued on Back Page)

$\gamma_{LL} = 1.00$ for Inventory Rating,
$\gamma_{LL} = \left({}^{1.35}/_{1.75}\right)$ for Operating Rating, and
$IM = 0$

Example

Assume a precast Exodermic® deck is selected to longitudinally span continuous over multiple floor beam supports spaced at 13'-6". Determine the Inventory and Operating Rating Factors. The design deck is as follows:

WT6x7 main bars @ 8"	5.0 ksi precast concrete
#6 @ 4" primary rebar	115 kcf concrete
1/4" x 2" cross bar @ 6"	2" cover over rebar
#4 @ 6" distribution rebar	1/2" sacrificial concrete (see note)
3/4" PPC overlay	4.25" total concrete thickness
0.160 kcf overlay	9.955 total deck height including overlay

Note: For the purpose of rating the deck, some owners specify that a sacrificial element need not be deducted from the concrete for calculation of section properties.

Dead Load Moment Calculations

M_{DC} = Dead Load Moment due to self weight — $M_{DC} = \frac{(W_{DC})L^2}{8}C$ — 1.3839 kip-ft./ft.

M_{DW} = Dead Load Moment due to future wearing surface — $M_{DW} = \frac{(W_{DW})L^2}{8}C$ — 0.2734 kip-ft./ft.

Pedestrian Live Load Moment Calculations

M_{PED} = Live Load Moment due to Pedestrian Live Loads — $M_{PED} = \frac{(W_{PED})L^2}{8}C$ — 0.0000 kip-ft./ft.

Live Load Moment Calculations from HL-93 Loading

$M_{LL\text{-transverse}}$ = 18.99 in kips/in= 18.9860 kip-ft./ft.

$M_{LL\text{-parallel}}$ = 22.15 in kips/in= 22.1457 kip-ft./ft.

Parallel to Traffic — M_{LL} = 22.1457 kip-ft./ft.

Moments from BGFMA V3.1 Design Program

	Force Effects (ksi) & Nominal Moment Capacity for Negative Bending (ft-kips/ft)			
Element Checked (Section Modulus with Units of in^3/ft)	Composite F_{yf_DC}	Composite $F_{yf\_DW} + F_{yf\_LL}$	Composite $\lvert F_{yf\_DC} + F_{yf\_DW} + F_{yf\_LL} \rvert$	Moment Capacity $\lvert \phi M_n \rvert$
Centroid of Strong Axis Rebar	1.8368	29.7564	31.5932	45.2052
Top of Main Bar	0.9167	14.8506	15.7673	75.4821
Top of Supplemental Bar	---- NA ----	---- NA ----	---- NA ----	---- NA ----
Top of Cross Bar	0.9167	14.8506	15.7673	75.4821
Top of CB Punch in MB	0.4260	6.9008	7.3268	162.4371
Bottom of CB Fillet Weld to MB	0.5487	8.8883	9.4369	126.1159
Bottom of CB Punch in MB	-0.0647	-1.0489	1.1137	1068.6904
Bottom of Main Bar	-1.5148	-24.5404	26.0552	45.6779
Bottom of Concrete (ø = 0.9)	---- NA ----	---- NA ----	---- NA ----	---- NA ----

Nominal Moment Capacity from BGFMA V3.1 Design Program

$$RF_I = \frac{45.2052\frac{kip-ft}{ft} - 1.3839\frac{kip-ft}{ft} - 0.2734\frac{kip-ft}{ft}}{(1.0)(22.1457\frac{kip-ft}{ft})} = 1.97$$

$$RF_O = \frac{45.2052\frac{kip-ft}{ft} - 1.3839\frac{kip-ft}{ft} - 0.2734\frac{kip-ft}{ft}}{({}^{1.35}/_{1.75})(22.1457\frac{kip-ft}{ft})} = 2.55$$