2.3. Live Loads on Bridge Superstructures

The live loads on highway bridges are represented by vehicular loading on the roadways of bridges. The first serious effort to quantify highway live loads was made in USA 1913, where the continuous work led to the first design live loads based on 10- and 15-ton trucks, followed in 1924 by a 20-ton truck. These trucks are known as H10, H15 and H20 trucks respectively, the letter (H) refers to highway and the (number) refers to total truck weight in tons. Accordingly, the effect of these live loads is determined from the largest of the followings:

- Truck loading.
- Equivalent loading.

2.3.1. Truck Loading

Firstly, the highway truck loading was quantified based on two-axle truck (H) and then semitrailer truck (HS) was adopted for heavy-loaded bridge. In 1944, configurations of trucks (Figure 2.5) were designated in AASHTO specifications with adding the year by two digits (44) the truck nomenclature. The 20-ton is the standard loading value used for design truck, the differences in percentage and total load (gross vehicle load) of truck are tabulated below.
where:
W: total weight of (H) trucks and combined weight on the first two axles of (HS) trucks.
GVW: gross vehicle weight which is the total truck weight.

Table 2.2: Difference between Standard Truck (HS20-44) and other Trucks

Truck	W kip	W/W of HS20	GVW kip
H10	20	0.50	20
H15	30	0.75	30
H20	40	1.00	40
HS15	30	0.75	54
HS20	40	1.00	72
HS25	50	1.25	90

In USA, industrial growth following after World War II created a demand for yet heavier loads to be carried on the American highway bridges. So that, HS25 loading which 25% heavier than HS20 trucks is adopted. Also, in line with countries development in transportation and trade fields, commercial vehicular loads are permitted and can be classified as follows:

- Legal loads.
- Exclusion vehicles.
- Overweight (permit) vehicles.

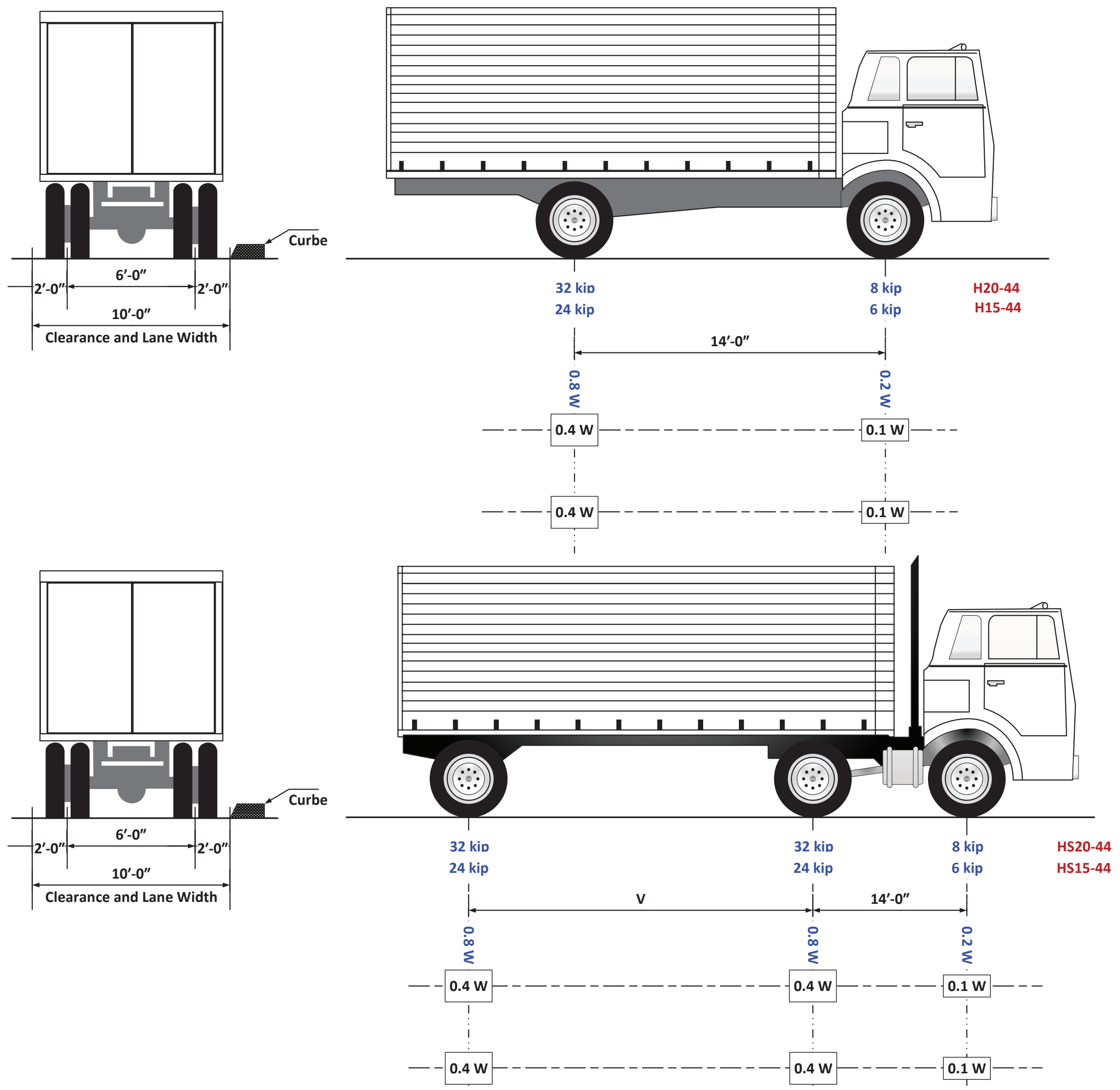


Figure 2.5: Configurations of Truck Loading According to AASHTO

2.3.2. <u>Equivalent loading</u>

Equivalent loading is a combined load consists of lane load which is uniformly distributed load is used a time with specific concentrated load for moment and another time with different concentrated load for shear as shown below.

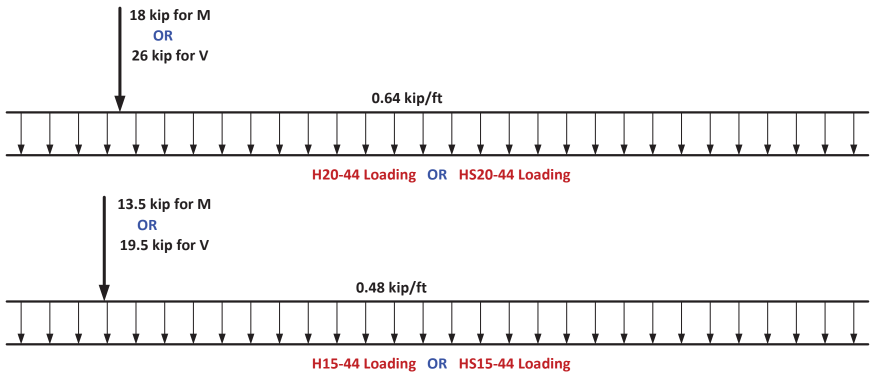


Figure 2.6: Standard Equivalent loading According to AASHTO

The standard specifications stipulate that moments, shears and any other forces are required to be determined separately as caused by the truck and the equivalent loading. Thus, the larger of the two values shall be used for design.

2.4. Vehicular Live Load

The vehicular live loading on the roadways of bridges or incidental structures is defined by AASHTO specifications, designated as HL-93 where HL means highway loading and 93 refers to year of officially approved (1993), shall consist of a combination of the (Figure 2.7):

- **Design Truck**: it is the HS20-44 truck as defined previously. To produce extreme force effects, the rare axles spacing shall be varied between 14 and 30 ft.
- **Design Tandem**: The design tandem shall consist of a pair of axles of 25-kip load and spaced 4 ft apart. The transverse spacing of wheels shall be taken as 6 ft.
- **Design Lane Load**: Uniformly distributed load of 0.64 kip/ft in the longitudinal direction. Transversely, the design lane load is assumed to be uniformly distributed over a width of 10 ft.

The tandem load, also known as the alternate military loading, is specified to simulate military loading and typically governs design of spans approximately shorter than 40 ft.

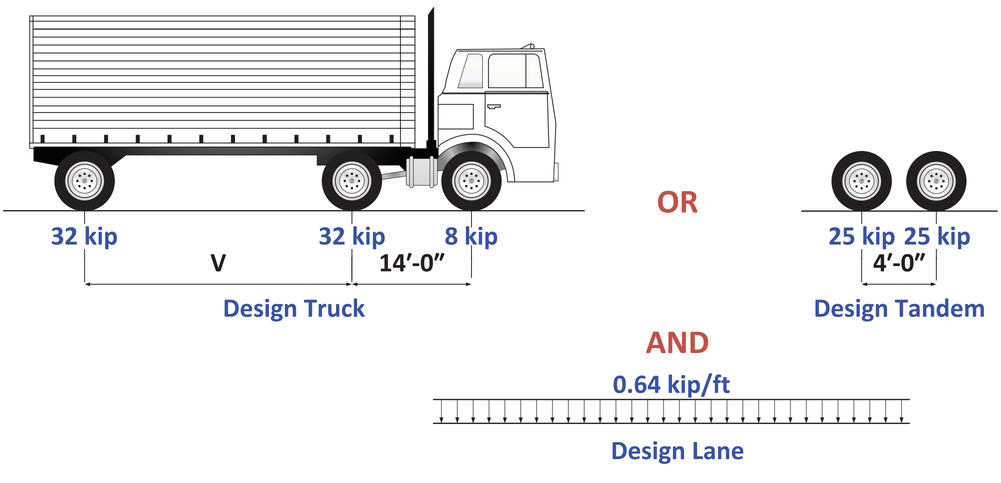


Figure 2.7:Combination of Vehicular Live Load According to AASHTO

2.4.1. Maximum Moment and Shear for Moving Load

The maximum bending moment or shear does not depend on the moving loads magnitudes only. However, the position of the moving load is more considerable. The critical position of the moving load on the bridge need to be determined by influence lines application.

So, the maximum moment caused by a moving load on simple beam can be computed instantaneously when the center of the simple span is at the middle distance between the resultant (R) of the moving load and its nearest axle load as shown in Figure 2.8.

To find the maximum bending moment of moving load (M_{Mo}) as truck (M_{Tr}) or tandem (M_{Ta}), follow that:

- Find the distance (X) between the resultant (R) of moving load and its nearest axle load.
- Then, neglect (R) and assume its nearest axle load lies at point (o) of distance $(0.5X)$ from the center of the span.
- Determine the positions of the other front and rear axles of the moving load on the span.
- Compute the supports reactions, then make a cut at point (o) to find the moment therein.

The maximum shear force (V_{Tr}) or (V_{Ta}) can be computed instantaneously on a support when the entire moving load is inside the span and its rear axle is closest to that support.

- If $L \geq 40.27$ ft $\rightarrow$ $M_{Mo} = M_{Tr}$
- If $L \geq 26$ ft $\rightarrow$ $V_{Mo} = V_{Tr}$

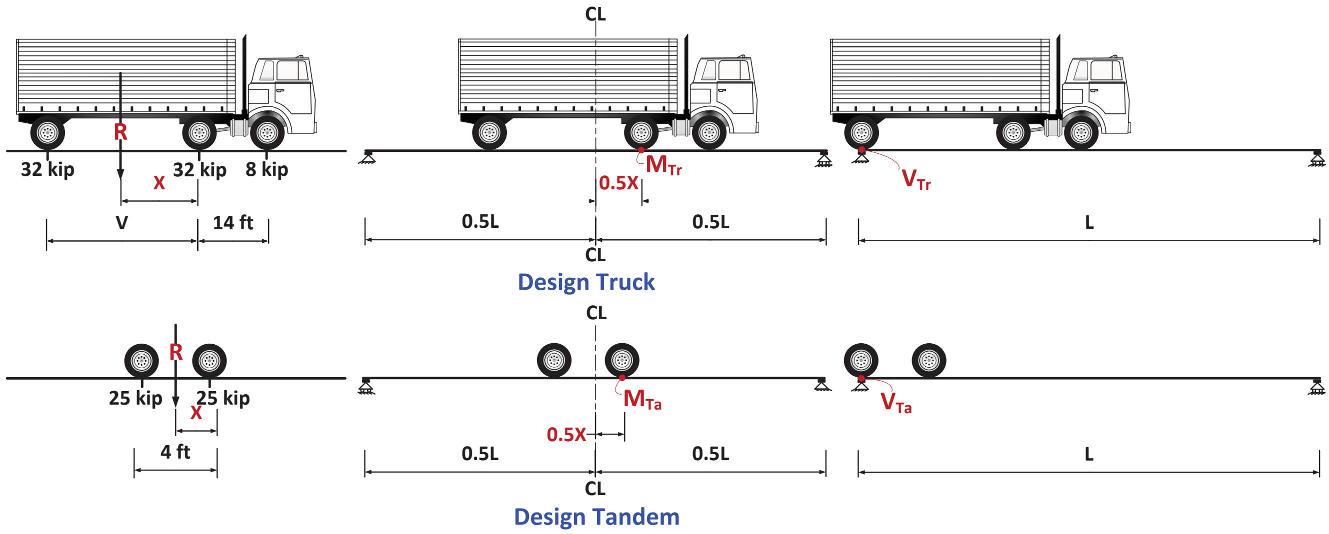


Figure 2.8: Maximum Moment and Shear Locations under Moving Load on Simple Spans

2.4.2. <u>Approximate Maximum Moment for Moving Load</u>

The maximum bending moment can be approximately calculated with acceptable results by positing the larger load from near axles to the resultant on the center line of the simple beam as in Figure 2.9.

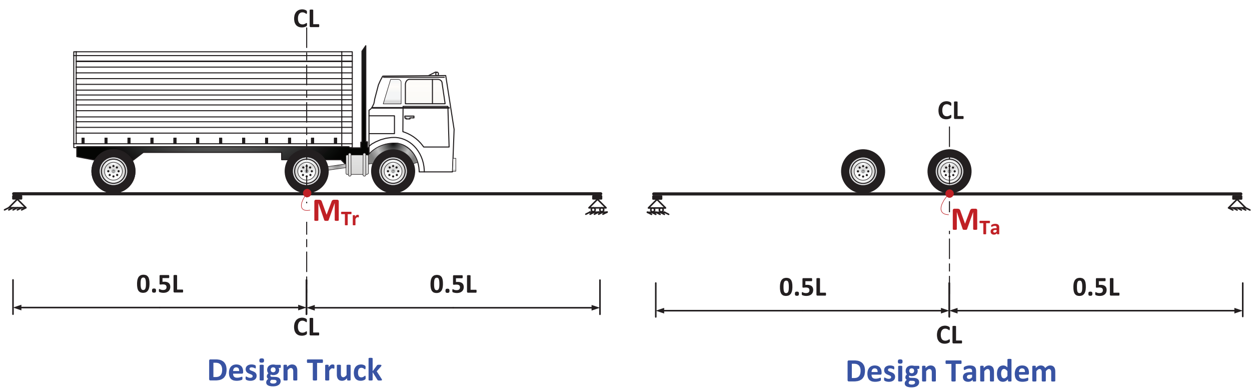


Figure 2.9: Approximate Maximum Moment under Moving Load on Simple Spans

2.4.3. Dynamic Load Allowance

It is clear that when a moving vehicle across a bridge at a specific speed, stresses are produced greater than ones when the vehicle remains static on the bridge.

The static effects of the design truck or tandem, other than centrifugal and braking forces on superstructure and other bridge portions above the ground level shall be increased by the percentage specified by AASHTO for dynamic load allowance (DLA).

The (DLA) factor (IM) to be applied to the static load shall be taken as: $(1 + IM)$.

In contrast, the (IM) shall not be applied to pedestrian loads or to the design lane load.

Table 2.3: Dynamic Load Allowance [AASHTO LRFD Table 3.6.2.1-1]

Component		DLA (IM)
Deck Joints	All Limit States	75%
All Other Components	Fatigue and Fracture Limit State	15%
	All Other Limit States	33%

2.4.4. Multiple Presence of Live Load

The multiple presence factor (m) is needed to investigate the position of vehicular Live Load, thereby, the design lane width (12 ft) is greater than the truck width (10 ft). So, the m factor is depending on number of loaded lanes (N_L) on the roadway of the bridge.

The m factor to be applied to the vehicular Live load shall be taken as: $m(Q_{Mo} + IM)$.

Possible future changes in the physical or functional clear roadway width of the bridge should be considered during determination of lanes. Roadway widths (10 – 12 ft) shall have two design lanes, each equal to one-half the roadway width. Thus, N_L is:

- $10 \le w < 20$ ft $\quad N_L = 1$
- $20 \le w \le 24$ ft $\quad N_L = 2$
- $w > 12$ ft $\quad N_L = INT(w/12)$

$$w = W - 2(W_e)$$

where:

w: the clear roadway width.

W: overall bridge width.

W_e: distance between the inside face of the curb and the edge of the deck.

Table 2.4: Multiple Presence Factor [AASHTO LRFD Table 3.6.1.1.2-1]

Number of Loaded Lanes (N_L)	Multiple Presence Factor (m)
1	1.20
2	1.00
3	0.85
> 3	0.65

Example 2.4

Determine the unfactored bending moment and shear force induced by vehicular live load to act on a simply-supported highway bridge. Take the span length is 25 ft.

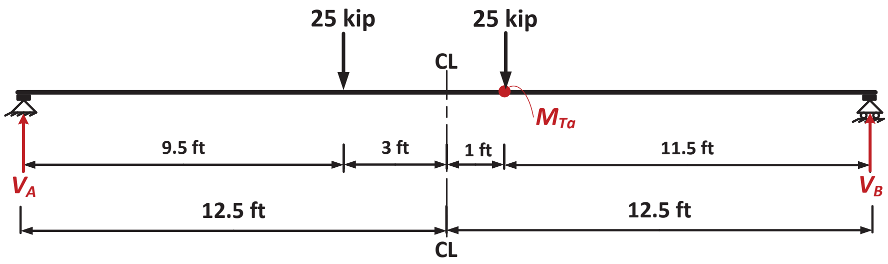
Solution 2.4

1. Determine unfactored bending moment

$w_{Ln} = 0.64$ kip/ft

$M_{Ln} = w_{Ln}.L^2/8 = 0.64(25)^2/8 = 50$ kip.ft

Since $L = 25$ ft < 42.27 ft $\rightarrow M_{Mo} = M_{Ta}$



$\Sigma M_B = 0 \curvearrowright^+$

$V_A\,(25) - 25(11.5 + 15.5) = 0$

$\therefore V_A = 27$ kip

$M_{Ta} = 27(13.5) - 25(4) = 264.5$ kip.ft

$IM = 0.33$

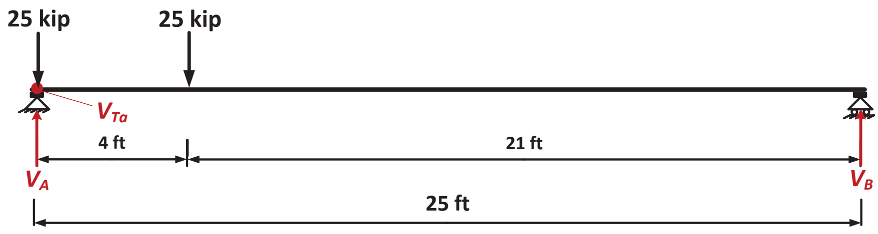
$M_{LL+IM} = (1 + IM)M_{Ta} + M_{Ln}$

$= 1.33(264.5) + 50 = 401.8$ kip.ft

2. Determine unfactored shear force

$V_{Ln} = w_{Ln}.L/2 = 0.64(25)/2 = 8$ kip

Since $L = 25$ ft < 26 ft $\rightarrow V_{Mo} = V_{Ta}$



$\Sigma M_B = 0 \curvearrowright^+$

$V_A\,(25) - 25(21 + 25) = 0$

$\therefore V_{Ta} = 46$ kip

$V_{LL+IM} = (1 + IM)V_{Ta} + V_{Ln}$

$= 1.33(46) + 8 = 69.2$ kip

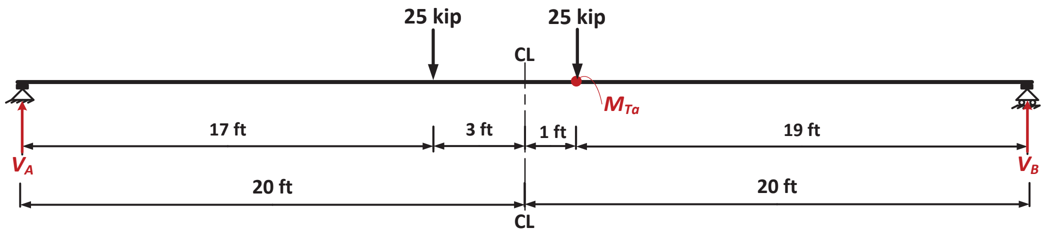
Example 2.5

Determine the unfactored bending moment and shear force induced by vehicular live load to act on a simply-supported highway bridge. Take the span length is 40 ft.

Solution 2.5

1. Determine unfactored bending moment

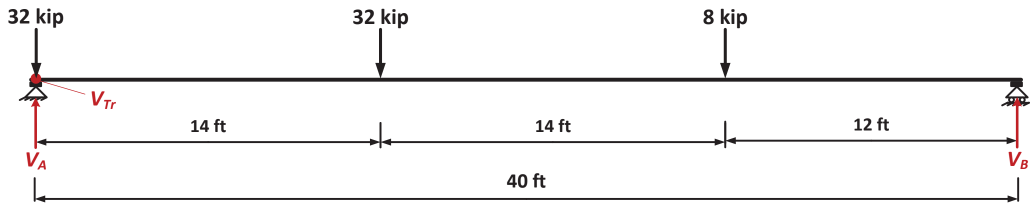
$$w_{Ln} = 0.64 \text{ kip/ft}$$
$$M_{Ln} = w_{Ln}.L^2/8 = 0.64(40)^2/8 = 128 \text{ kip.ft}$$
$$L = 40 \text{ ft} < 42.27 \text{ ft} \rightarrow M_{Mo} = M_{Ta}$$



$$\Sigma M_B = 0 \curvearrowright^{+}$$
$$V_A(40) - 25(19 + 23) = 0$$
$$\therefore V_A = 26.3 \text{ kip}$$
$$M_{Ta} = 26.3(21) - 25(4) = 452.3 \text{ kip.ft}$$
$$IM = 0.33$$
$$M_{LL+IM} = (1 + IM)M_{Ta} + M_{Ln}$$
$$= 1.33(452.3) + 128 = 729.6 \text{ kip.ft}$$

2. Determine unfactored shear force

$$V_{Ln} = w_{Ln}.L/2 = 0.64(40)/2 = 12.8 \text{ kip}$$
$$L = 40 \text{ ft} > 26 \text{ ft} \rightarrow V_{Mo} = V_{Tr}$$



$$\Sigma M_B = 0 \curvearrowright^{+}$$
$$V_A(40) - 8(12) - 32(26 + 40) = 0$$
$$\therefore V_{Tr} = 55.2 \text{ kip}$$
$$V_{LL+IM} = (1 + IM)V_{Tr} + V_{Ln}$$
$$= 1.33(55.2) + 12.8 = 86.2 \text{ kip}$$

Example 2.6

Determine the unfactored bending moment and shear force induced by vehicular live load to act on a simply-supported highway bridge. Take the span length is 50 ft.

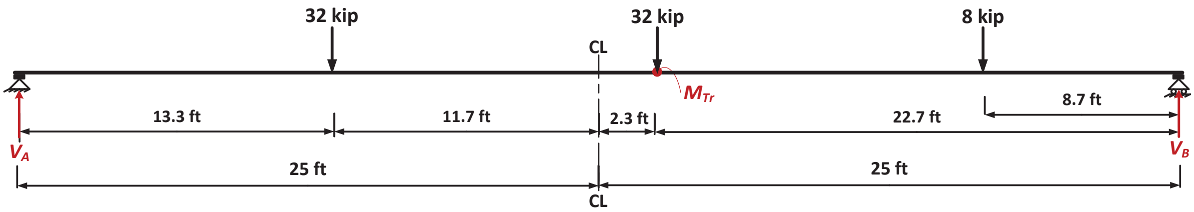
Solution 2.6

1. Determine unfactored bending moment

$$w_{Ln} = 0.64 \text{ kip/ft}$$

$$M_{Ln} = w_{Ln}.L^2/8 = 0.64(50)^2/8 = 200 \text{ kip.ft}$$

$$\text{Since } L = 50 \text{ ft} > 42.27 \text{ ft } \rightarrow M_{Mo} = M_{Tr}$$



$$\Sigma M_B = 0 \ \curvearrowright^+$$

$$V_A(50) - 8(8.7) - 32(22.7 + 36.7) = 0$$

$$\therefore V_A = 39.4 \text{ kip}$$

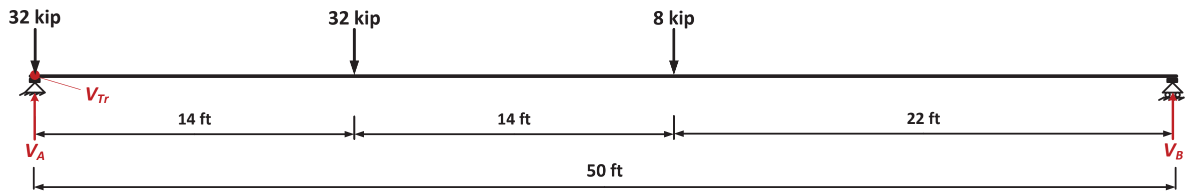
$$M_{Tr} = 39.4(27.3) - 32(14) = 627.6 \text{ kip.ft}$$

$$M_{LL+IM} = (1 + IM)M_{Ta} + M_{Ln} = 1.33(627.6) + 200 = 1034.7 \text{ kip.ft}$$

2. Determine unfactored shear force

$$V_{Ln} = w_{Ln}.L/2 = 0.64(50)/2 = 16 \text{ kip}$$

$$L = 50 \text{ ft} > 26 \text{ ft } \rightarrow V_{Mo} = V_{Tr}$$



$$\Sigma M_B = 0 \ \curvearrowright^+$$

$$V_A(50) - 8(22) - 32(36 + 50) = 0$$

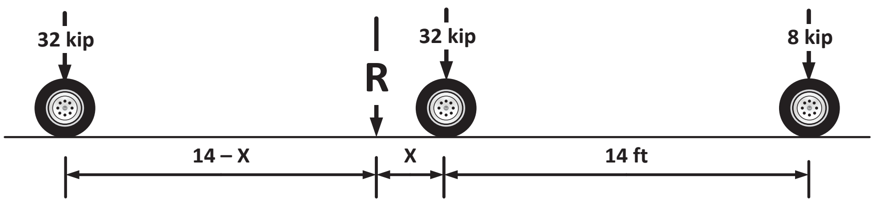
$$\therefore V_{Tr} = 58.6 \text{ kip}$$

$$V_{LL+IM} = (1 + IM)V_{Tr} + V_{Ln}$$

$$= 1.33(58.6) + 16 = 93.9 \text{ kip}$$

Note for truck critical position to determine maximum bending moment

$$R = \text{GVW} = 8 + 32 + 32 = 72 \text{ kip}$$



$\Sigma M_o = 0 \ \curvearrowright^+$ point o lies at the center axle

$$8(14) - 32(14) - 72X = 0$$

$\therefore X \cong 4.6$ ft the distance between R and its nearest axle load