• What is Military Load Classification?
• International Documents
• Bridge MLC Testing Overview
• Vehicle MLC Calculation Procedure
• Summary
WHAT IS A MILITARY LOAD CLASSIFICATION (MLC)?

• Definition: A number representative of the load carrying capacity of gap-crossing equipment (e.g. bridges, rafts) and the effect produced by a military vehicle crossing over a bridge
  – MLC = f(vehicle weight, vehicle geometry (e.g. length, width))

• Purpose: Used to assess the capability of a military vehicle to use gap-crossing equipment without damaging it
  – Enables User to determine required gap-crossing equipment to support a particular mission
  – Helps to improve safe use of bridges and other gap-crossing equipment

• MLC of military vehicle, bridge marked in accordance with NATO Standard AEP-3.12.1.5
CCDC GVSC Bridging is involved in the working groups for the following documents:

- NATO STANAG 2021 (Standard AEP-3.12.1.5)
- Trilateral Design and Test Code for Military Bridging and Gap Crossing Equipment (TDTC)
• NATO Standard establishing method for calculating the Military Load Classification (MLC) for bridges, military ferries and rafts, and military vehicles.
  – Mandates use of reference software, under the responsibility of national official authorities, as the only means to determine vehicle’s official MLC
    • GVSC Bridging is national authority for the United States

• Establishes hypothetical tracked and wheeled vehicles
  – 16 standard tracked and 16 standard wheeled MLCs between MLC 4 and MLC 150 inclusive
  – Hypothetical vehicle characteristics for MLCs between these standard values may be calculated through linear interpolation

Official NATO Standard AEP-3.12.1.5 Statement on MLC/Vehicle Weight Relationship

THE MILITARY LOAD CLASSIFICATION NUMBER IS ONLY A NUMBER, IT DOES NOT REPRESENT THE MASS OF THE VEHICLE
• 32 total (16 tracked, 16 wheeled)
• Establishes standard tracked, wheeled classes for use in military bridge design, testing
• Also used for width correction for vehicle MLC calculation
• All hypothetical vehicle widths measured from outside to outside (e.g. outside tire to outside tire)
### HYPOTHETICAL VEHICLES (FROM APPENDIX C, TDTC)

#### SI Units (note: tonnes = metric tons)

<table>
<thead>
<tr>
<th>MLC</th>
<th>Tracked Vehicles</th>
<th>Wheeled Vehicles</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Axle Load [Tonnes] and Spacing [m]</td>
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<tr>
<td>150</td>
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#### US Customary Units

<table>
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TRILATERAL DESIGN AND TEST CODE FOR MILITARY BRIDGING AND GAP CROSSING EQUIPMENT (TDTC)

• Primary design and test guide for military bridging
• Managed in cooperation with the United Kingdom and Germany
• Provides loading conditions (e.g. mud load, vehicle crossing speeds, bank bearing pressures) which must be considered when designing for a particular MLC
• Provides methodology followed by Army for testing of military bridges at a particular MLC
BRIDGE MLC TEST OVERVIEW

• TDTC provides general test procedure, parameters, evaluation criteria
• Requires at least two bridges to complete full test program
• Two Steps:
  – Step 1: Bridge Rating Qualification (Structural Strength)
    • Two required tests
      – Working Load (equal to bridge design load)
      – Overload (1.33 x Working Load)
    • Ultimate Load (1.5 x Working Load) performed if necessary
    • Hypothetical vehicle footprints used for load application
BRIDGE MLC TEST OVERVIEW

– Step 2: Bridge Rating Confirmation (Durability)
  • Consists of live, simulated crossings
  • 3 parts
    – Test to required number of crossings \((n)\) per requirements document
    – Continue test to \(1.5n\)
    – Continue test to achieve 95% confidence of 95% exceedance
      » \(n\) multiplied by factor based off of number of samples to determine # crossings
  • Test to fatigue failure may be performed after 95% confidence of 95% exceedance achieved
## INFORMATION REQUIRED FOR MLC CALCULATION

**Tracked Vehicle**

<table>
<thead>
<tr>
<th>Vehicle Weight (tons)</th>
<th>Length of Track in Contact with Ground (in)</th>
<th>Vehicle Width (in)</th>
<th>Location of Vehicle Width Measurement (fill out only if Vehicle Width was not measured from Outside Track to Outside Track)</th>
</tr>
</thead>
</table>

**Wheeled Vehicle**

<table>
<thead>
<tr>
<th>Axle</th>
<th>Axle Load (tons)</th>
<th>Distance from Axle 1 (in)</th>
<th>Axle Spacing (in)</th>
<th>Tire Footprint Length (in)</th>
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</tbody>
</table>
1. Calculate maximum unit bending moment and shear force produced by vehicle at reference spans (1-100 m)
   – Unit Bending Moment = Max Moment / span

2. Determine Rough MLC through Linear Interpolation between hypothetical vehicle bending moment, shear force curves at the point which gives the highest MLC
Figure 5: unit bending moments of tracked vehicles (spans 1 to 100 m)

Figure 7: shear forces of tracked vehicles (spans 1 to 100 m)
MLC CALCULATION PROCEDURE CONT.

Figure 1: Unit bending moments of wheeled vehicles (spans 1 to 100 m)

Figure 3: Shear forces of wheeled vehicles (spans 1 to 100 m)
3. Compare the actual vehicle’s width with the width of the hypothetical vehicle whose MLC is closest to the Rough MLC and apply a width correction factor, if necessary
   – Width correction factor applied if Actual Vehicle is narrower than hypothetical vehicle

4. Round calculated MLC from Step 3 to the nearest whole number to obtain final MLC

Slope of line = 6/25.4 (6% per 25.4 cm width)
MLC CALCULATION PROCEDURE
SUMMARY

1. Calculate maximum unit bending moment and shear force produced by vehicle at reference spans (1-100m)
2. Determine Rough MLC through linear interpolation between hypothetical vehicle bending moment and shear force curves at the point which gives the highest MLC.
3. Perform width comparison between the actual vehicle and hypothetical vehicle with MLC closest to the rough MLC and apply a width correction factor, if necessary
4. Round calculated MLC from Step 3 to the nearest whole number to obtain the final MLC
Calculate the final MLC for the vehicle whose bending moment curve is represented by the green line.

-Vehicle Weight = 20 tonnes, Width = 2.3 m, Contact Length = 3.35 m
1) Calculate the rough MLC at each span location through linear interpolation

EX:
At 60 m
UBM for MLC 20 Hypothetical Tracked Vehicle = 45.69 kN
UBM for MLC 24 Hypothetical Tracked Vehicle = 54.83 kN
UBM for Actual Vehicle = 49.45 kN

\[
\frac{54.83 - 45.69}{24 - 20} = \frac{49.45 - 45.69}{MLC - 20}
\]

\[
(54.83 - 45.69)(MLC - 20) = (49.54 - 45.69)(24 - 20)
\]

\[
MLC \approx 21.6
\]

For the vehicle in this example, maximum rough MLC = 21.92
2) Compare vehicle width with width of hypothetical vehicle representative of the rough MLC and calculate Width Correction Factor, if necessary

- MLC 22 Tracked Vehicle Width = 2.49 m > 2.3m

Width Correction Required

\[
\text{WidthCorrection} = 1 + \left[ \frac{6\%}{25.4cm} \times \left( \frac{100cm}{1m} \times (2.49m - 2.3m) \right) \times \frac{1}{100\%} \right]
\]

\[
\text{WidthCorrection} = 1.0449
\]

3) Calculate Final MLC

\[
MLC = \text{MaximumRoughMLC} \times \text{WidthCorrection}
\]

\[
MLC = 21.92 \times 1.0449
\]

\[
MLC = 22.9
\]

\[
MLC \approx 23
\]

Vehicle’s MLC = 23
EXAMPLE: ABRAMS MLC/ VEHICLE WEIGHT RELATIONSHIP

Up to 70 tons: Abrams MLC = Abrams Weight
Beyond 70 tons: Abrams MLC ≠ Abrams Weight -> Non-Linear Increase

<table>
<thead>
<tr>
<th>Abrams Weight (US tons)</th>
<th>Final Abrams MLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.25</td>
<td>71</td>
</tr>
<tr>
<td>71</td>
<td>73</td>
</tr>
<tr>
<td>75</td>
<td>83</td>
</tr>
<tr>
<td>80</td>
<td>99</td>
</tr>
</tbody>
</table>
Changing vehicle width results in changes to vehicle’s MLC
Vehicle length changes have more significant effect on vehicle MLC.
EXAMPLE: M1A2 SEPv3 @ MLC 114
Bending Moment Plots

- 84 ton SEPv3 bending moment tracks between MLC 100, MLC 120 at spans up to 16 feet
  - Max MLC before width correction = 101
- 84 ton SEPv3 bending moment tracks between MLC 80, MLC 90 at spans greater than 23 feet
  - At 148 ft (45 m), MLC before width correction = 84
  - At 328 ft (100 m), MLC before width correction = 85
SUMMARY

• MLC Calculation Method established by NATO Standard AEP-3.12.1.5
• MLC does NOT equal vehicle weight
  – Vehicle geometry also factors into the calculation

Calculation of a vehicle’s Military Load Classification is dependent not only on vehicle weight, but also on vehicle geometry.
Backup
WHEELED EXAMPLE 1 – SMALL WHEEL CALCULATION

- Maxx Pro Dash w/ Spark II Roller
  - Total Load = 29.5 tons

- No width correction applied – Vehicle is wider than hypothetical MLC 32 wheeled vehicle
WHEELED EXAMPLE 2 – LARGE WHEEL CALCULATION

- Same vehicle as in Wheeled Example 1 – No changes to axle loads or spacing

- Additional Parameter added for calculation = Footprint Size (length of tire footprint)
EXAMPLE: MAX MOMENT CALCULATION FOR WHEELED VEHICLE

Bridge Span = L

Step 1: Determine Location of CG (CG = total weight of vehicle)

\[ CGx = 0.375W \times 0.25L + 0.375L \times (0.25 + 0.5)L \]

\[ x = \frac{1}{CG} (0.375W \times 0.25L + 0.375L \times (0.25 + 0.5)L) \]

\[ x = 0.375L \]
EXAMPLE: MAX MOMENT CALCULATION FOR WHEELED VEHICLE

Step 2: Place vehicle on span so that CG and axle closest to it are equidistant from the center of the span

Step 3: Calculate Reaction at D and E

Moment Balance About D

\[ EL = 0.25W \times 0.1875L + 0.375W \times 0.4375L + 0.375W \times 0.9375L \]

\[ E = 0.5625W \]

Vertical Force Balance

\[ D = 0.25W + 0.375W + 0.375W - E \]

\[ D = 0.4375W \]
EXAMPLE: MAX MOMENT CALCULATION FOR WHEELED VEHICLE

Step 4: Construct Shear Force Diagram

Step 5: Calculate Max Moment = Max Area Under the Shear Force Curve

\[ M_{\text{max}} = 0.4375W \cdot 0.1875L + 0.1875W \cdot 0.25L = 0.1289WL \]

Max Moment ≈ 0.1289WL
EXAMPLE: LENGTH OF TRACK IN CONTACT WITH GROUND = L

Distributed Load = W/L

Bridge Span = 2L

Step 1: Calculate Reactions at the Supports

Moment Balance About B

\[ A = \frac{WL}{2L} = \frac{W}{2} \]

Vertical Force Balance

\[ B = W - A = \frac{W}{2} \]
EXAMPLE: LENGTH OF TRACK IN CONTACT WITH GROUND = L

Step 2: Generate Shear Force Curve

Step 3: Calculate Max Moment = Maximum Area Under Shear Force Curve

\[ M_{\text{max}} = \text{Area}_1 + \text{Area}_2 = \frac{W \times L}{2} + \frac{1 \times W \times L}{2} = \frac{3WL}{8} \]

Max Moment = 0.375WL
EXAMPLE: LARGE WHEEL CALCULATION

Step 1: Determine Location of CG (CG = total weight of vehicle)

Moment Balance About Beginning of Convoy

\[
CGx = \frac{12.5W}{L}(0.02L)(0.01L) + \frac{18.75W}{L}(0.02L)(0.25L + 0.01L) + \frac{18.75W}{L}(0.02L)(0.75L + 0.01L)
\]

\[
x = 0.385L
\]
**EXAMPLE: MAX MOMENT CALCULATION FOR WHEELED VEHICLE**

**Step 2:** Place vehicle on span so that CG and end of axle closest to it are equidistant from the center of the span.

![Diagram of vehicle placement on span](image)

**Step 3:** Calculate Reaction at D and E

**Moment Balance About D**

\[ EL = \frac{12.5W}{L}(0.02L)(0.1775L) + \frac{18.75W}{L}(0.02L)(0.4275L) + \frac{18.75W}{L}(0.02L)(0.9275L) \]

\[ E = 0.5525W \]

**Vertical Force Balance**

\[ D = \frac{12.5W}{L}(0.02L) + \frac{18.75W}{L}(0.02L) + \frac{18.75W}{L}(0.02L) - E \]

\[ D = 0.4475W \]
Step 4: Construct Shear Force Diagram

Step 5: Calculate Max Moment = Max Area Under the Shear Force Curve

\[ M_{\text{max}} = A_1 + A_2 + A_3 + A_4 \approx 0.1278WL \]

Max Moment \( \approx 0.1278WL \)
ABRAMS CALCULATION EXAMPLE 1

• 70 ton M1A2
  – Track Length = 180.2 in
  – Width = 137.01 in

• Width correction based on MLC
  70 tracked hypothetical width
  • Width = 138.189 in (3.51 m)
  • Correction Factor ~ 1.0071
ABRAMS CALCULATION EXAMPLE 2

- Weight increased to 74 tons (combat weight)
- Width correction now based on MLC 78 tracked hypothetical
  - Width = 142.913 in (3.63 m)
  - Correction Factor ~ 1.035
ABRAMS CALCULATION EXAMPLE 3

- **78 ton M1A2**
  - Track Length = 180.2 in
  - Width = 137.01 in

- Width correction now based on MLC 87 tracked hypothetical
  - Width = 148.228 in (3.765 m)
  - Correction Factor ~ 1.067
GEOMETRY EFFECT EXAMPLE 1A

- 70 ton Tank
  - Track Length = 180 in
  - Width = 138 in

- Width correction based on MLC 70T Hypothetical Vehicle Width
  - Width = 138.189 in (3.51 m)
  - Correction Factor ~ 1.00113
GEOMETRY EFFECT EXAMPLE 1B

- **70 ton Tank**
  - Track Length = 179 in
  - Width = 138 in

- Slight increase in rough MLC compared to Example 1
- Width correction now based off of MLC 71T theoretical vehicle width
  - Width = 138.78 in (3.525 m)
  - Correction Factor ~ 1.00468
GEOMETRY EFFECT EXAMPLE 1C

- **70 ton Tank**
  - Track Length = 180 in
  - Width = 137 in

- 1 inch reduction in width from Example 1 results in greater width correction factor, higher MLC than that calculated in Example 1
  - Width Correction Factor ~ 1.00713 vs 1.00113 in Example 1