Alaska Department of Transportation & Public Facilities

TAC Bridges

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Topics

1. Safety
2. Bridge Capacity & Load Ratings
3. Bridge Fatigue
4. Monitoring Plan
5. Alternate Routes
6. Address TAC Questions

Bridge Safety

Safety is always 1st priority.

By federal law and Department policy, access to bridges is limited or bridges are closed if they are unsafe.

Middle Fork Koyukuk River 1

6/14/23 – damage reported to Dept. Lane was closed same day and repairs were started the next week.

6/30/23 – work completed

Questions

1. Most of the bridges scheduled for replacement along the corridor will not be replaced prior to the Kinross ore haul and will be used for the entirety of the ore haul, with perhaps two being complete prior to its end. **How will Kinney evaluate bridge safety, damage assessment and enhanced inspection plans prior to replacement?**

2. ADOT/PF bridge section engineer Elmer Marx noted the Kinross ore haul trucks will exceed the inventory rating of 17 bridges along the route. Heavy LCV traffic will increase over 100% along much of the route. **Will Kinney, or another independent subcontractor, quantify the impacts of 60 heavy LCVs per day exceeding the inventory rating of 17 bridges along the route?**

Bridge Safety

A bridge is safe when…

Capacity > Load

Bridge Safety

Improved with safety factors…

$$\phi_C \times \text{Capacity} > \gamma_L \times \text{Loads}$$

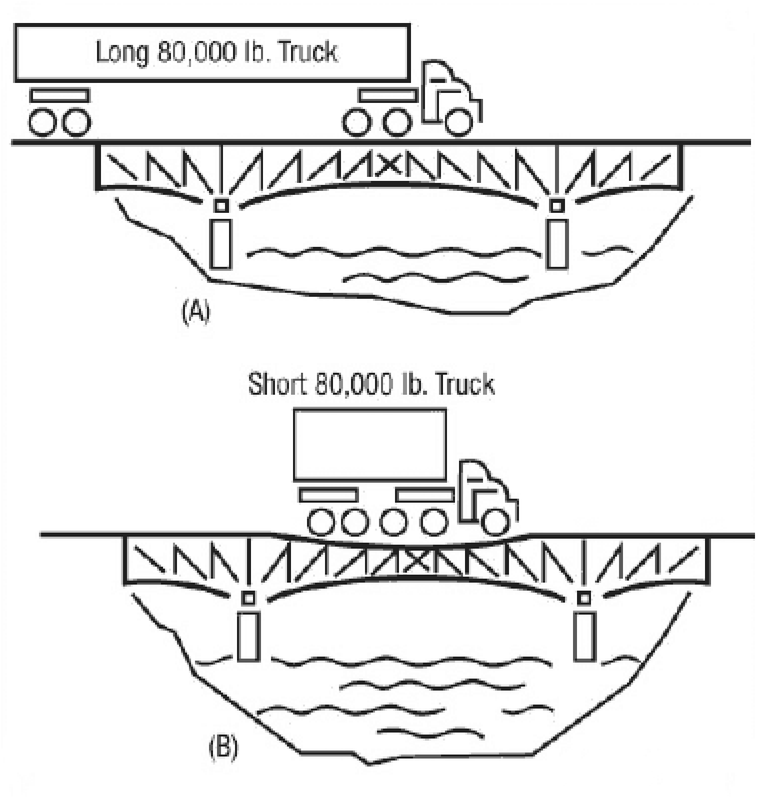
ϕ_C = capacity safety factor < 1.0

γ_L = load safety factor > 1.0

Load Ratings

Load ratings determine how loads affect a bridge

- Axle weights and spacing are more important than Gross Vehicle Weight (GVW)
- Densely spaced loads can influence bridge more than well spaced loads



Source: https://ops.fhwa.dot.gov/freight/publications/brdg_frm_wghts/

Load Ratings

Design & load rating vehicles are "notional" loads

- Not actual vehicles
- Represent a combination of statistically-calibrated vehicles types
- Legal loads don't require a permit
- Permit loads exceed legal loads

Load Ratings

Rating Factor = $$\frac{\phi_C (\boldsymbol{Capacity}) - \gamma_D (\boldsymbol{Dead\ Load})}{\gamma_L (\boldsymbol{Live\ Load})}$$

- **Inventory Rating:** The load level that can safely use an existing structure for an indefinite period of time. (*Alaska Bridges and Structures Manual*)

Inventory Rating Factor = $$\frac{(\boldsymbol{Capacity}) - (\boldsymbol{Dead\ Load})}{\boldsymbol{2.17}\ (\boldsymbol{Live\ Load})}$$

Load Ratings

- **Operating Rating**: The maximum permissible live load to which the structure may be subjected for the load configuration used in the load rating. Allowing unlimited numbers of vehicles to use the bridge at operating level may shorten the life of the bridge... (23 CFR § 650.305)

$$\text{Operating Rating Factor} = \frac{(\boldsymbol{Capacity}) - (\boldsymbol{Dead\ Load})}{\mathbf{1.3}\ (\boldsymbol{Live\ Load})}$$

Load Rating used to determine Load Posting

- National regulations (23 CFR 650 and *AASHTO Manual for Bridge Evaluation*): owners must post bridges for Operating Load Rating (i.e., not Inventory)

- *Alaska Bridges and Structures Manual*: must consider posting when Inventory Rating is HS 15, i.e., Inventory Rating Factor = 0.75

- Only 5 States in US use inventory rating for posting

Extra Safety Factors

Department policy is to exceed minimums required by Codes as documented in *Alaska Bridges and Structures Manual*

- Bridge designers and load rating engineers make conservative assumptions
- Examples:
  - Use minimum concrete and steel strengths which may be higher
  - Ore haul vehicle is a known load but use load factors as if unknown/notional load

Ore Haul Load Rating

Ore haul vehicle does not exceed the “multi-lane with impact operating rating” *except* at the Chena Hot Springs UC and Chena Flood Channel Bridges.

- CHS UC (Limit = 26.06 HS, Load = 28.96 HS)
- Chena Flood Channel NB (Limit = 22.90 HS, Load = 22.98 HS)

*HS = HS20 Truck = 36 tons

Metric 13 Review & Plan of Corrective Action (PCA)

- Metric 13 = load rating compliance
- Alaska needs to determine how the Alaska statute vehicle allowances differ from notional vehicles in the *AASHTO Manual for Bridge Evaluation*
- Consultant Research Study will be ~1 year with ~2 years to implement (June 1, 2026 completion)
- Potential outcomes include different load rating vehicles, a modification factor to existing vehicles, or no changes
- Service inventory load ratings – states must do load ratings, <u>but are not required to use for posting</u>

Load Ratings & PCA

- PCA will not change anything about the haul vehicle load ratings because that is a known load and bridge capacity side of the equation was not questioned
- PCA does not involve load posting (Metric 14)

Fatigue

- Understanding of bridges largely based on research by Dr. John Fischer at Lehigh University starting in ~1950s.
- Only applies to steel (i.e., tension members)
- Concrete does not experience fatigue; reinforcing steel within concrete can experience fatigue but largely restricted by concrete which is in compression.
  - For example, the Code states that concrete deck fatigue is usually well below infinite fatigue life levels, so fatigue need not be checked.
- Need a “flaw” for a crack to initiate due to fatigue

Fatigue Definitions

AASHTO LRFD Bridge Design Specifications, 9th ed

- *Constant Amplitude Fatigue Threshold*—The nominal stress range below which a particular detail can withstand an infinite number of repetitions without fatigue failure.
- *Detail Category*—A grouping of components and details having essentially the same fatigue resistance.
- *Fatigue*—The initiation and/or propagation of cracks due to a repeated variation of normal stress with a tensile component.
- *Fatigue Design Life*—The number of years that a detail is expected to resist the assumed traffic loads without fatigue cracking. In the development of these Specifications, it has been taken as 75 years.
- *Fatigue Life*—The number of repeated stress cycles that results in fatigue failure of a detail.
- *Fatigue Resistance*—The maximum stress range that can be sustained without failure of the detail for a specified number of cycles.
- *Finite Fatigue Life*—The number of cycles to failure of a detail when the maximum probable stress range exceeds the constant amplitude fatigue threshold.
- *Required Fatigue Life*—A product of the single-lane average daily truck traffic, the number of cycles per truck passage, and the design life in days.

Fatigue Equation

AASHTO Manual for Bridge Evaluation, 3rd ed

If $(\Delta F)_{max} \leq (\Delta F)_{TH}$ then have infinite fatigue life (7.2.4-1)

Otherwise check for finite life:

$$Y = \frac{\log\left[\frac{R_R A}{365n\left[(ADTT)_{SL}\right]_{PRESENT}\left[(\Delta f)_{eff}\right]^3} g(1+g)^{a-1} + 1\right]}{\log(1+g)} \quad (7.2.5.1\text{-}1)$$

where:

R_R = Resistance factor specified for evaluation, minimum, or mean fatigue life as given in Table 7.2.5.1-1

A = Detail-category constant given in LRFD Design Table 6.6.1.2.5-1

n = Number of stress-range cycles per truck passage estimated according to Article 7.2.5.2

g = Estimated annual traffic-growth rate, percent, expressed as a decimal; i.e., 5 percent = 0.05

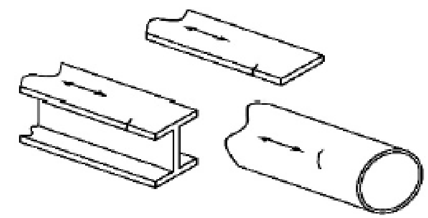
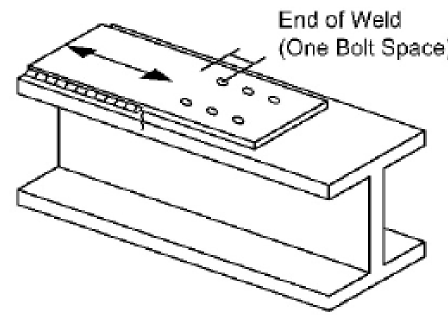
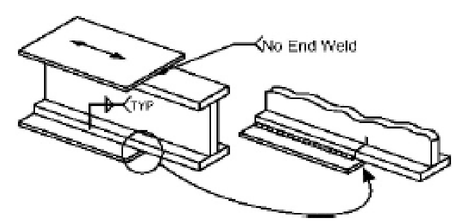
a = Present age of the detail in years

$[(ADTT)_{SL}]_{PRESENT}$ = Present average number of trucks per day in a single lane

$(\Delta f)_{eff}$ = The effective stress range as specified in Article 7.2.2

Fatigue Category

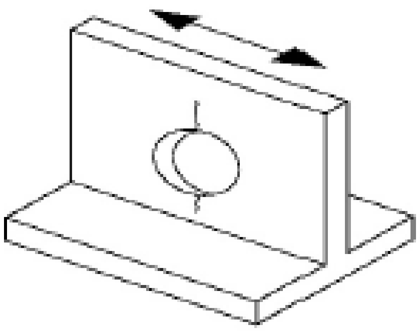
Determined by testing of various details

Description	Category	Constant A $(ksi)^3$	Threshold $(\Delta F)_{TH}$ ksi	Potential Crack Initiation Point	Illustrative Examples
Section 1—Plain Material away from Any Welding					
1.1 Base metal, except noncoated weathering steel, with rolled or cleaned surfaces, or base metal with thermal-cut edges with a surface roughness value of 1,000 μ-in. or less, but without re-entrant corners.	A	250×10^8	24	Away from all welds or structural connections	
Section 3—Welded Joints Joining Components of Built-Up Members (continued)					
3.6 Base metal at the termination of partial length welded cover plates with slip-critical bolted end connections satisfying the requirements of Article 6.10.12.2.3.	B	120×10^8	16	In the flange at the termination of the longitudinal weld	
3.7 Base metal at the termination of partial length welded cover plates that are wider than the flange and without welds across the ends.	E′	3.9×10^8	2.6	In the edge of the flange at the end of the cover plate weld	

Fatigue Threshold

If fatigue loading stress is below Threshold, have infinite fatigue life and no fatigue failure

$(\Delta F)_{max} < (\Delta F)_{TH}$



Rivets = C   (MBE 7.2.1)

Table 6.6.1.2.5-3—Constant-Amplitude Fatigue Thresholds

Detail Category	Threshold (ksi)
A	24.0
B	16.0
B′	12.0
C	10.0
~~C′~~	~~12.0~~
~~D~~	~~7.0~~
~~E~~	~~4.5~~
~~E′~~	~~2.6~~
ASTM F3125/F3125M, Grades A325 and F1852 Bolts in Axial Tension	31.0
ASTM F3125/F3125M, Grades A490 and F2280 Bolts in Axial Tension	38.0

Fatigue Example

Robertson River Bridge Fatigue Calculations

$(\Delta F)_{max} < (\Delta F)_{TH}$ for infinite life

Truck	Stress (ksi)	Factored Stress, $(\Delta F)_{max}$ (ksi)	OK for Detail Categories
AASHTO	4.64	8.2	A - C
Ore Haul	7.89	13.8	A, B

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If the number of cycles is below the threshold, there is no fatigue failure

- CAFT = constant amplitude fatigue threshold

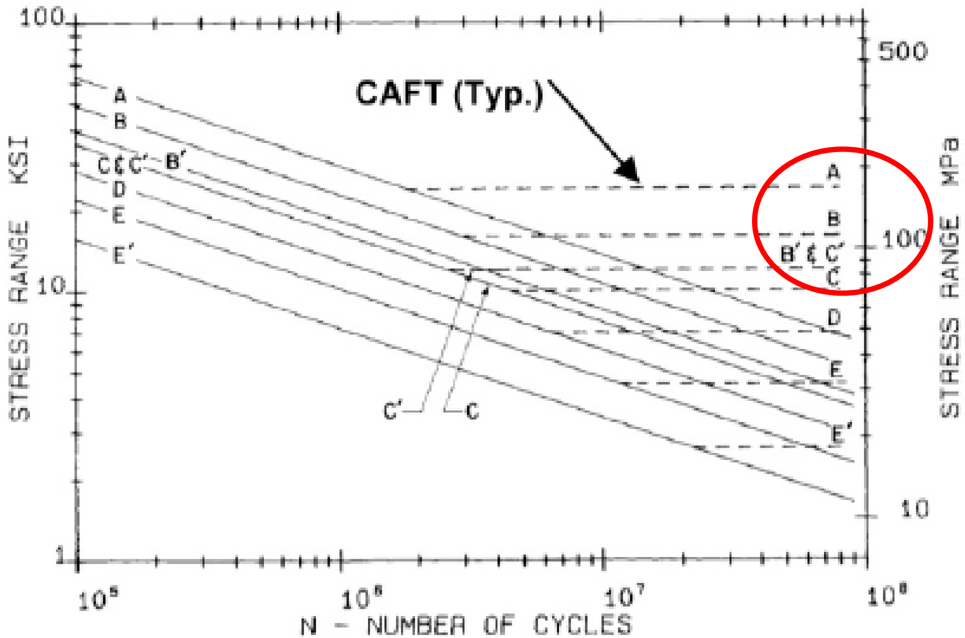


Figure C6.6.1.2.5-1—Stress Range Versus Number of Cycles

Fatigue Example

Calculate Number of Cycles – Robertson River Br.

Number of cycles, N = 365 (years in service)($ADTT_{SL}$)

Average ADT @MP1359 from 1998 to 2022 = 297

- with 19% trucks ADTT = 56
- assume single lane is $ADTT_{SL}$ = 28

Regular trucks: N = 365 (85) (28) = 868,700 = 8.687×10^5

Ore haul trucks*: N = 365 (5) (60) = 109,500 = 0.11×10^5

*full trucks so one-way only

Fatigue Example

Miner's Rule

- Sum of number of cycles over number of cycles to failure at the level equals a certain number (3 for structural steels)
- Use to find "Equivalent Stress Range" or "Weighted Average"

$$\sum \frac{n_i}{N_i} = 1$$

$$S_{re} = \left(\sum \gamma_i S_{r_i}^3\right)^{\frac{1}{3}}$$

Vehicle Type	ADTT	Years	Cycles (AADT * Years * 365 days)	Percent of Vehicles, γ_i	S_{ri} (ksi)	S_{ri}^3 (ksi)^3	$\gamma_i S_{ri}^3$ (ksi)^3	Percent
AASHTO H20	28	85	868,700	88.8%	8.2	551.368	489.65	62.5%
Ore Haul	60	5	109,500	11.2%	13.8	2628.072	294.19	37.5%
Total			978,200	100.0%			783.83	100.0%
Values for S-N Curve:			**9.78E+05**			**S_{re} =**	**9.2**	**ksi**

S-N Curve with AASHTO & Ore Haul Vehicles

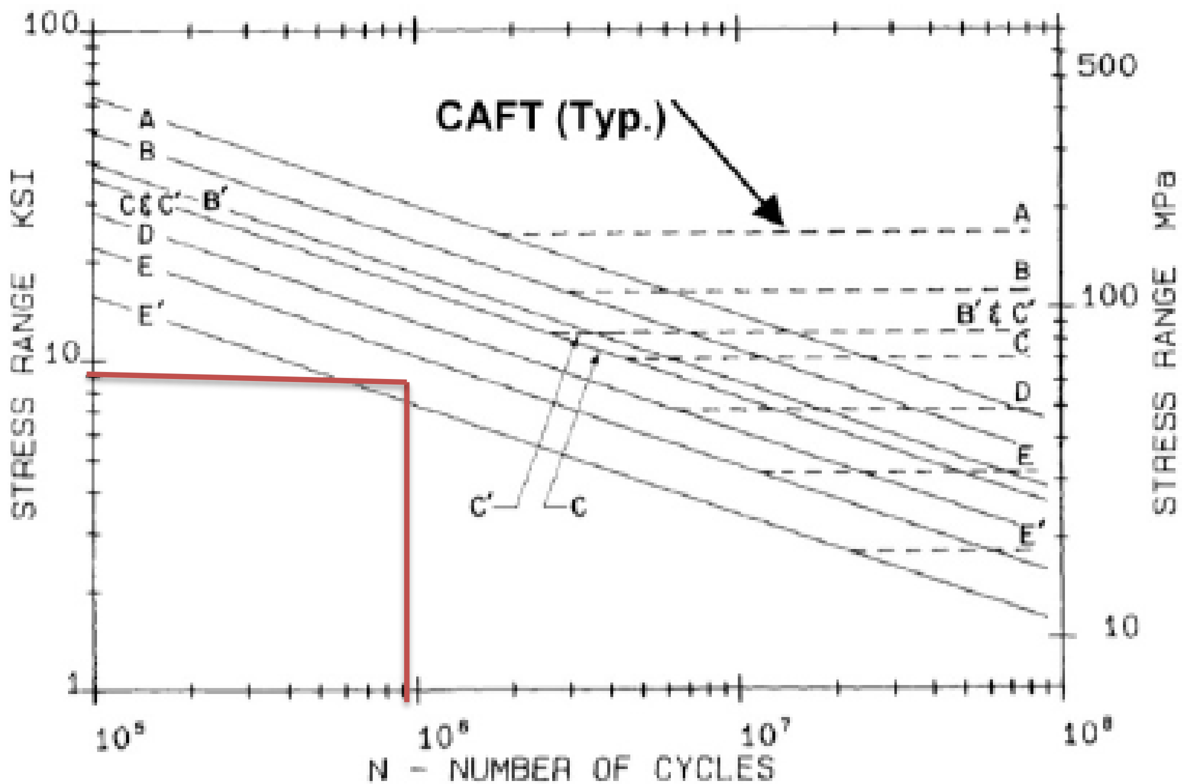


Figure C6.6.1.2.5-1—Stress Range Versus Number of Cycles

Fatigue Equations – Finite Life

$$Y = \frac{\log\left[\frac{R_R A}{365n\left[(ADTT)_{SL}\right]_{PRESENT}\left[(\Delta f)_{eff}\right]^3} g(1+g)^{a-1} + 1\right]}{\log(1+g)} \quad (7.2.5.1\text{-}1)$$

Table 7.2.5.1-1—Resistance Factor for Evaluation, Minimum or Mean Fatigue Life, R_R

Detail Category (from Table 6.6.1.2.5-1 of the *LRFD Specifications*)	R_R			
	Minimum Life	Evaluation 1 Life	Evaluation 2 Life	Mean Life
A	1.0	1.5	2.2	2.9
B	1.0	1.3	1.7	2.0
B'	1.0	1.3	1.6	1.9
C	1.0	1.3	1.7	2.1
C'	1.0	1.3	1.7	2.1
D	1.0	1.3	1.7	2.0
E	1.0	1.2	1.4	1.6
E'	1.0	1.3	1.6	1.9

6.1.2.5-2—Cycles per Truck Passage, n

Longitudinal Members	
Simple Span Girders	1.0
Continuous Girders: 1) near interior support 2) elsewhere	 1.5 1.0
Cantilever Girders	5.0
Orthotropic Deck Plate Connections Subjected to Wheel Load Cycling	5.0
Trusses	1.0
Transverse Members	
Spacing > 20.0 ft	1.0
Spacing ≤ 20.0 ft	2.0

Assuming g = 1% and R_R = Min. Life (worst case), if haul continues for 5 years, the ***estimated*** remaining fatigue life is 24.8 years.

Fatigue Example

Golden Gate Bridge

- Completed in 1938 so 85 years old
- Total of 2,389,688,053 vehicles as of 2020*
- Say 1% truck traffic = 238,968,805 cycles = 2.39 x 10^8 cycles
- Bridge has not failed so has not surpassed fatigue threshold, does not have flaws, and/or cracks were repaired

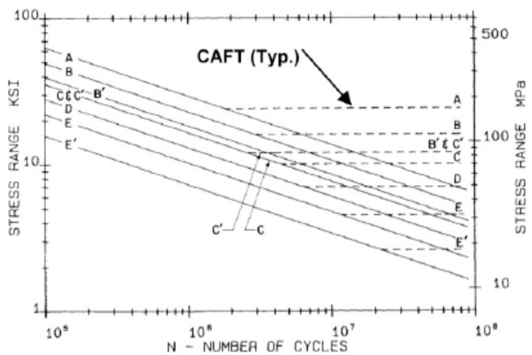


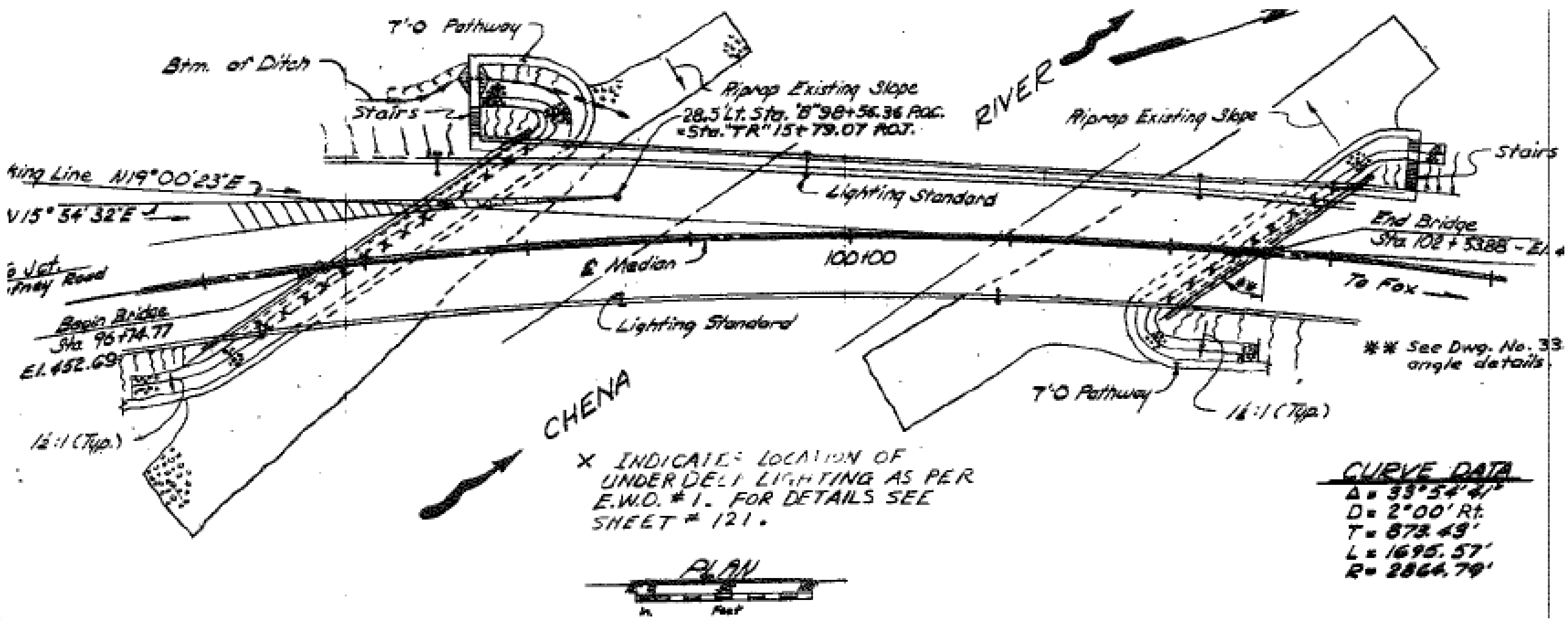
Figure C6.6.1.2.5-1—Stress Range Versus Number of Cycles

- ~75% of fatigue life is used to start a crack, so ~25% of life before full failure

*source: https://www.goldengate.org/bridge/history-research/statistics-data/annual-vehicle-crossings-toll-revenues/

Chena River at Steese Bridge #231

- Complicated bifurcated structure with high-strength (less ductile) steel
- Historically not allowed overloads on this bridge



Monitoring Plan

Monthly monitoring for 3 months after haul begins

- Single span bridges with visual
- Multiple span bridges with visual and drones
- Appropriate preventative action will be taken if deterioration is found

Why Replace These Bridges?

Trusses

- Fracture critical, restrict vertical/horizontal traffic, not designed to modern seismic standards, maintenance is expensive, etc.
- Already replaced 2 trusses on AK Highway; the Rex Bridge on the Parks is programed for replacement; Takotna & Tatalina trusses (Central Region) have bid for replacement

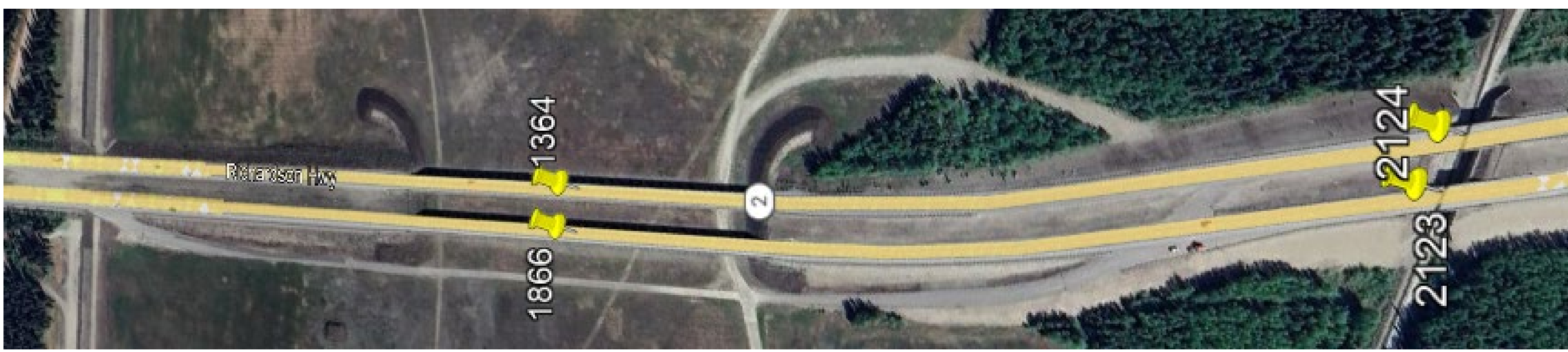
Why Replace These Bridges?

Chena Flood

- Low shear ratings have historically caused denies for permit loads (e.g. southbound bypass)
- Not practical to retrofit piers for seismic capacity

Chena Hot Springs Road

- Shear ratings issue for North Slope traffic
- Has bypass

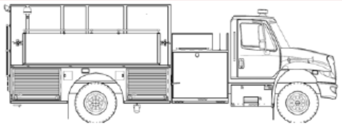


Questions

Can you please tell us what this weight limit sign means? We’ve never seen such a posting “Emergency Vehicle Weight Limit.” These appear to be newly installed…

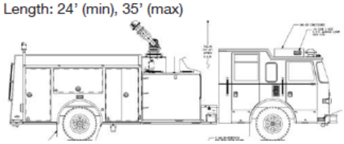
Emergency Vehicles

Emergency Vehicles with Two Axles		Emergency Vehicles with Three Axles	

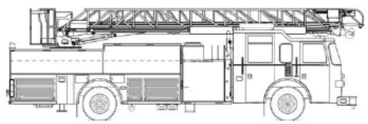


COMMERCIAL CHASSIS PUMPER
GVW: 16.5 T (min), 24.5 T (max)
Length: 24' (min), 35' (max)

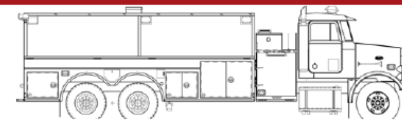
CUSTOM CHASSIS PUMPER
GVW: 21 T (min), 27.5 T (max)
Length: 30' (min), 34' (max)



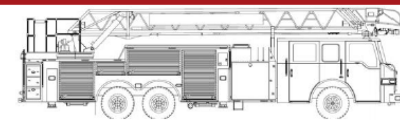
INDUSTRIAL FOAM PUMPER
GVW: 22 T (min), 27.5 T (max)
Length: 30' (min), 36' (max)



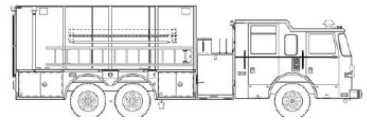
AERIAL LADDER
GVW: 22 T (min), 28.9 T (max)
Length: 36' (min), 43' (max)



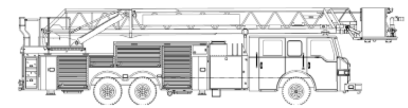
COMMERCIAL CHASSIS TANKER
GVW: 23 T (min), 37 T (max)
Length: 30' (min), 40' (max)



AERIAL LADDER
GVW: 27 T (min), 38.4 T (max)
Length: 39' (min), 43' (max)



CUSTOM CHASSIS TANKER
GVW: 29.3 T (min), 39.4 T (max)
Length: 24' (min), 35' (max)



AERIAL PLATFORM REAR MOUNT
GVW: 33.7 T (min), 43 T (max)
Length: 46' (min), 48' (max)

Figures from Fire Apparatus Manufacturers' Association (FAMA), Emergency Vehicle Size and Weight Guide.

- GVW limit is 86,000 lbs
- Water is heavy and EVs have close axle spacing (i.e., loads more concentrated than regular trucks)
- EV is a notional vehicle
- Johnson & Gerstle are signed

TAC Questions

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