



**MASSACHUSETTS BAY TRANSPORTATION
AUTHORITY**



**GUIDE SPECIFICATIONS
FOR
STRUCTURAL DESIGN
OF
RAPID TRANSIT AND
LIGHT RAIL STRUCTURES**

October 2005

Gannett Fleming



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GANNETT FLEMING

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INTRODUCTION

This Guide Specification for the Structural Design of Rapid Transit and Light Rail Structures was developed to establish the minimum design requirements for Massachusetts Bay Transportation Authority (MBTA) owned structures including bridges, culverts, retaining walls, and all structural elements that carry Rapid Transit vehicles.

Design Specifications from various Transit Agencies served as the basis for the development of this Guideline Specification. Other references include American Railroad Engineering and Maintenance of Way Association (AREMA), American Association for State Highway and Transportation Officials (AASHTO), research reports, specific information pertaining to MBTA, and historic /environmental data for the Boston Metropolitan area.

Specific information relating to cars, power, communication, signals, tracks, maintenance, and operation should be obtained directly from the Authority's relevant divisions and departments.

The development of this Guide Specification was done under the leadership of the MBTA Bridge Management Division and the collaborative efforts of the various Authority divisions such as Maintenance of Way, Power/Transmission and Distribution, Vehicle Procurement, Signals and Communications, Subway Operations, Design Department, Car-house professionals, and Gannett Fleming, Inc. as the consultant. Ms. Elizabeth Ozhathil, P.E., Project Manager compiled the basic documents for this Guide Specification and coordinated development efforts throughout the draft and final stages of this Guide Specification.

This Guide Specification will be implemented to the extent possible. It will be the responsibility of the design engineer to evaluate the specifics of the structure under consideration, identify conditions where deviations from the specific requirements or additional requirements are needed to ensure the adequacy of the design. The design engineer shall report to the Authority such conditions and recommend any deviation/additional requirement the engineer considers necessary to be implemented for successful completion of the design and construction of the structure.

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY

GUIDE SPECIFICATIONS
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1. Scope

1.1. General

These Guide Specifications establish the basic design criteria for Massachusetts Bay Transportation Authority (MBTA/Authority) owned structures including bridges, culverts, retaining walls, and all structural elements that carry Rapid Transit and Light Rail vehicles.

The Guide Specifications are considered minimum requirements. The design of structures shall comply with these Guide Specifications to the maximum extent possible. Where special design cases are encountered that are not specifically covered by these Guide Specifications, the designer shall determine and submit, to the Authority for approval, supplemental technical sources to comply with the state and federal regulations and codes listed in Section 2 below.

Structures shall be designed and detailed with due consideration to the loading and environmental conditions they will be subjected to during the lifespan of the structure. Structural materials and details shall be selected to allow any needed maintenance and repairs to be performed without significant interruptions to transit service. Rehabilitation and repairs shall be designed and detailed with due consideration of the historic architecture of the structure. New structures shall be designed for a minimum lifespan of 80 years.

Unless otherwise noted, the word transit shall herein after refer to both the Rapid Transit and Light Rail systems.

1.2. Units

The English units shall be used for all transit structure projects.

2. Applicable Codes and Specifications

2.1. General

Structural design shall be governed by the latest edition of the applicable codes including all interims, manuals, standards, and specifications that are defined in this section of the criteria. Any deviations or exceptions to the design codes or specifications shall require prior approval by the Authority.

Where applicable codes are issued on SI units only, such codes will be utilized after conversion to English units.

When more than one code or requirement is applicable, the most stringent code and requirement shall govern unless directed otherwise by the Authority.

2.2. MBTA Codes

The following codes shall be used as minimum base codes on all MBTA projects and shall govern over other codes unless noted otherwise or authorized by the Authority. All codes must be the current version with all supplements

- The MBTA "Track Maintenance Standards Manual"
- The MBTA "Standard Specifications, Construction"
- The MBTA "Standard Line Items"
- The MBTA "MBTA Railroad Operations – Commuter Rail Design Standards Manual"
- The MBTA "MBTA Railroad Operations - Book of Standard Plans - Track and Roadway"

All pertinent track materials are to be stamped "APPROVED" by the MBTA Maintenance of Way Engineering.

All preliminary designs that may impact existing signal and communication apparatus are to be reviewed by the Signal and Communications Division for approval.

All design work that impact power including catenary wires and cables shall be reviewed and approved by the Power Division.

2.3. Transit Structure

Bridges and aerial structures and parts of structures that support transit loading as defined in these guide specifications shall comply with the design requirements specified in this Guide and

the “Standard Specifications for Highway Bridges”, Seventeenth Edition with interim specifications¹, of the American Association of State Highway and Transportation Officials (AASHTO), hereinafter referred to as “AASHTO Bridges”.

In addition, the “Manual for Railway Engineering”, of the American Railway Engineering and Maintenance of Way Association, hereinafter referred to as the “AREMA”, will be used where indicated.

2.4. Railroad Structures

For bridges and aerial structures that support commuter rail, railway loadings, and freight trains, the design requirements of AREMA shall be used as amended by the requirements of the railroad owner.

For bridges and aerial structures that support a combination of transit rail and commuter rail, railway loadings, or freight trains, the design requirements of AREMA shall be used as amended by the requirements of the railroad and transit rail owners.

2.5. Highway Structures

For bridges and aerial structures that support highway loadings, the current edition of the AASHTO codes shall be used. In addition, the current Massachusetts Highway Department (MHD) design standards shall be used.

2.6. Buildings

For building structures and parts of structures that are subject to transit loading, the structural design shall be governed by these Guide Specifications as well as the current edition of the Massachusetts State Building Code.

2.7. Earth Retaining Structures

The guidelines set forth in AREMA shall be used in the design of earth retaining structures supporting transit loadings except as modified herein.

2.8. Culverts

The guidelines set forth in AREMA shall be used in the design of culverts carrying transit loadings except as modified herein.

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¹ It is unlikely that AASHTO 17th Edition will have interims as LRFD design is expected to replace the LFD Design.

2.9. Masonry Structures

For concrete masonry structures and parts of concrete masonry structures that are not subject to transit, railway, or highway loading, the current edition of the Massachusetts State Building Code, and Specifications for Masonry Structures, ACI 530.1 shall be used.

2.10. Timber Structures

For timber structures, other than those subjected to transit, railway, or highway loading, the current edition of the "National Design Specification for Stress-Grade Lumber and its Fastenings" recommended by National Forest products Association shall be used.

2.11. Construction Documents

The construction documents for all structures shall be in accordance with the current MBTA construction standards including the MBTA Standard Specifications, Construction.

2.12. Track Alignment and Geometry

2.12.1. Track Clearance

Track alignment, track clearances, vehicle clearance from the centerline of track to adjacent structures, catenary trolley wire clearance, emergency guardrail, vertical restraining rail requirements, etc shall comply with requirements of the MBTA "Track Maintenance Standards Manual" set forth by the Authority.

Obtain written approval from the Maintenance of Way Division, Power Division, Signals and Communications Division, Safety Department, and the Subway Operations Department at the MBTA for all track clearances prior to completing the preliminary design phase.

3. Design Method

Strength Design Method (Load Factor Design LFD) shall be used for the design of the structures, the structural components and connections, earth retaining structures, and culverts subjected to transit loading. Live load deflections, fatigue, crack control, and vibration characteristics as well as permanent deflections under overloads shall also be investigated under service loading to assure serviceability and durability. Additional design requirements may apply based on type and configuration of the structure and structural elements.

AASHTO Load and Resistance Factor Design Method (LRFD) shall only be used when directed in writing by the Authority.

Provision shall be made for all loads, resulting from suggested methods to be used for the

transportation, installation, and subsequent removal and replacement of various items by equipments that may be utilized in the construction and maintenance of the structure.

4. Loads and Forces

4.1. General

Structures or parts of structures subjected to transit loadings shall be designed considering loads and forces defined herein, and including loads due to system wide elements such as electrification, signalization and communication equipment where and when applicable. Other loads and forces need to be considered when there is a probability that the structure maybe subjected to such forces. Modification to the design capacity of the structure under such load should be approved by the Authority based on the probability of occurrence of such loads. The loading criteria and all other loads to which the structures are designed shall be shown on the structural drawings.

Loads from adjacent buildings or structures shall be included in the design loadings where applicable. Considerations shall be given to the maximum and minimum loads which can be transferred to the design structure and design loads shall be assumed as those for which the adjacent structure was designed. In the absence of specific information, provision in the applicable codes for the actual weights and the heaviest loadings for which the structure is suitable for shall be used. Horizontal and vertical distribution of loads from foundations of existing structures shall be determined in consultation with the geotechnical design engineer.

4.2. Dead Load (DL)

Dead load shall consist of the actual weight of all components of the structure and all elements that are permanently supported by the structure. This load includes but is not limited to the weight of track, ballast, ties, utilities, electrification including third rail and fasteners, signalization and communication equipments, and all other permanent fixtures on the structure.

For unit dead load of materials, refer to the latest edition of the Massachusetts State Building Code and the AASHTO Bridges. Designers shall consult with the MBTA Maintenance of Way Division (MOW), Signal and Communication Division, and Power Division for specific weight of materials used by the MBTA. The unit weight of materials comprising the dead load, except in special cases involving unusual conditions or materials, shall be assumed as follows, unless revised by the Authority:

- Track rails, inside guardrails and fastenings 200 lb per linear foot of track
- Ballast, including track ties 120 lb per cubic foot
- Sand, gravel, and earth filling materials..... 120 lb per cubic foot
- Granite..... 170 lb per cubic foot
- Asphalt-mastic and bituminous macadam 150 lb per cubic foot
- Paving bricks 150 lb per cubic foot
- Normal weight reinforced concrete..... 150 lb per cubic foot

- Steel..... 490 lb per cubic foot
- Timber..... 60 lb per cubic foot
- Electrification including third rail and fasteners60 lb per linear foot
- Utilities including scuppers, drain pipes, and light poles.....200 lb per linear foot
- Waterproofing and protective covering Actual weight

Consideration shall be given to any system or facility such as piping, conduits, rigid stainless steel conduits, manholes, transformer vaults, tiebreaker houses, cables, pulling irons, catenary, and other services that will apply a load or force or cause a force to be transmitted to the design structure.

Special consideration should also be given to overhead and underground MBTA power cables. These cables are either 13,800-volt AC or 600-volt DC cables. Consult with the Power Division for type, location, and special requirement for these cables.

4.3. Vehicle Live Load (LL)

Vehicle Live Load shall consist of any non-permanent forces induced on the structure by transit vehicles, work train or other moving objects, construction loads, and loads due to maintenance operations.

For structures carrying multiple tracks, use AREMA multiple tracks load combinations unless noted otherwise.

4.3.1. Transit Revenue Car Loads

Train live loading shall consist of a continuous train of revenue cars with axle spacing and loads as shown in Appendix A. A summary of transit revenue car load and configuration is shown in Table 1.

Car/Line	Red Line	Orange Line	Blue Line	Green Line	High Speed Red Line**
Car Type	# 3 Car	# 12 Car	# 5 Car	# 7 SRC	PCC Car
Empty Car Load (lbs)	76,885	68,780	69,000	85,500	40,035
Max Crush Load (lbs)	42,935	34,720	22,630	41,580	18,200
Total Load (lbs)	119,820	103,500	91,630	127,080	58,235
Design Load (lbs)	128,000	120,000	102,000	137,000	68,000
Number of cars consist	6	6	6	3	2

** - High Speed Red Line will also be designed for #7 cars (SRC) - 1 to 2 cars.

Table 1- Transit Revenue Car Loads

Designer shall consult with the Authority for type of cars and car combinations

4.3.2. Transit Work Car Loads

Work train loading shall consist of a train of work cars with a configuration and loads as

shown in Appendix A. Work Cars typically travel at a speed of 30 to 40 mph. A summary of transit work cars is shown in Table 2

Car Type	Design Total Load (lbs)	Design Axle Load (lbs)
#0526 Flat Car	76,400	19,100
#01400 Motor Car	114,000	28,500
#04441 Flat car with Crane	100,000	25,000
#04443 700HP Diesel Locomotive	100,000	25,000
#04446 Flat Car	102,400	25,600
#04447 Flat Car	102,400	25,600
#04449 Flat Car	100,000	25,000
Ballast Car	76,000	38,000
Tamper Car	70,000	35,000
Tamper Car (50 Ton)	100,000	25,000

Table 2- Transit Work Car Loads

4.3.3. Car Combinations

Any combination of revenue car lengths and loadings (a minimum of a single car consist to a maximum specified in Table 1 above) which produces the most critical loading conditions for bending, axial, shear and torsional stresses, as well as deflections, fatigue, and stability shall be used for the design.

Extra-Ordinary-Car consist should be considered as a special case where applicable. This case represents a disabled revenue train being pushed by another revenue train. The combined length of both trains will be twice the typical length of train consist. Design shall be based on train speed of 20 MPH and adjacent tracks loaded with typical consist revenue trains without reduction in speed. Group IA load combination will be used for this special case.

Train work car combinations for all lines are shown in Table 3. A single or a multiple work car combination up to those shown in Table 3 should be evaluated.

Type	Work Car Combinations
I	700HP Diesel Locomotive (#04443) + Two Ballast Cars + One Tamper
II	Two flat cars (#04446/#04447) + Flat car with crane (#04441)
III	700HP Diesel Locomotive (#04443) + Flat Car (#0526)
IV	Flat Car (#04449) + four work motor cars (#01400 series)
V	700HP Diesel Locomotive (#04443) + four ballast cars.
VI*	700HP Diesel Locomotive (#04443) + two ballast cars followed by 700HP Diesel Locomotive (#04443) + two ballast cars followed by 700HP Diesel Locomotive (#04443) + two ballast cars.

* This Combination shall be used for long and multiple span structures to provide worst loading condition. There will be 1,000 ft distance between moving trains on the same track at full speed. This distance diminishes to zero for stationed trains.

Table 3 - Transit Work Car Load Combinations

A combination of revenue car train consists on one or two tracks and work train on the other track should be considered as a special load case. Group IA load combination will be used for this special case.

4.3.4. Impact Load (I)

Calculation of Impact Load shall comply with AASHTO Bridges. Impact fraction shall be calculated in accordance with formulas of AASHTO Bridges except as follows:

- Impact Load on deck shall be 40% of the wheel load, except for ballasted area where it will be 33% of the wheel load.
- Impact Load on stringers and short beams (less than 30 ft) in direct contact with the ties or rail shall be 75% of the total live load.
- Impact Load on continuous longitudinal beams in the negative moment region shall be 40% of the total live load.
- Impact load shall not exceed 33% of the total live load for all other elements.

The Impact Load may be reduced subject to the Authority's approval.

4.3.5. Nosing Force (NF)

Provision shall be made for a transverse horizontal force (nosing force) equal to 10% of the axle load without impact. This force shall be applied horizontally in the vertical plane containing each axle and shall be assumed to act normal to the track through a point 3.5 feet above the top of the rail. The horizontal force component transmitted to the rails and supporting structure by an axle shall be concentrated at the rail having direct wheel-flange-to-rail-head contact.

Alternatively, a single transverse horizontal force equal to 30% of the leading axle load without impact shall be applied to act in the same position as the nosing force mentioned above and at one axle only per car. The force that would provide the worst loading condition will be utilized.

4.3.6. Centrifugal Force (CF)

For structures on curves, provision shall be made for a horizontal radial force, equal to a percent of the specified axle load without impact, applied as a concentrated load at the axle location 5.0 feet above the top of the low rail on all tracks.

$$CF = 0.00117S^2 D$$

The relationships between speed, degree of curve, centrifugal force and a superelevation which is 3 inches less than that required for zero resultant flange pressure between wheel and rail are expressed by the formulas:

$$S = \sqrt{[(E+3)/0.0007D]}$$
$$E = 0.0007 S^2 D - 3$$

Where:

- CF = Centrifugal force in percentage of the live load
- D = Degree of curve
- E = Actual superelevation in inches
- S = Permissible speed in miles per hour

Consult with the MBTA Subway Operations Department for actual posted speed on the structure.

4.3.7. Rolling Force (RF)

A force equal to 10% of the axle loading (20% of the wheel loading) per track shall be applied downward on one rail and upward on the other, on all tracks.

For structures carrying more than two tracks, apply AREMA Impact Forces combination rules to the combination of Rolling Forces.

4.3.8. Longitudinal Breaking and Traction Force (LF)

Longitudinal forces generated by the acceleration and deceleration of revenue/work trains shall be taken as 15% of the live load, without impact, applied 5.0 feet above the top of low rail. Consideration is to be given to combinations of acceleration and deceleration forces where more than one track occurs. For double track structures, three longitudinal loading cases shall be considered:

- Single track loaded; longitudinal force acting in any one direction.
- Both tracks loaded; one train accelerating while the other train is decelerating, or both trains traveling in the same direction. Both longitudinal forces acting in the same direction.
- Both tracks loaded; both trains accelerating and decelerating. Longitudinal forces acting in opposite directions.

4.3.9. Derailment Load (DR)

Derailment load is defined as a vertical load that is produced by the train live loading placed with its longitudinal axis parallel to the track. The derailment load shall consist of the train live loading multiplied by an impact fraction. An impact fraction of 100% shall be used for the deck design and short span beams and stringers (less than 30 ft) in direct contact with the ties or rail (multiply wheel load by 2.0). An impact fraction of 33% shall be used for other girders and applicable substructure design (multiply wheel load by 1.33). Derailment load shall not be less than the impact load applied to the structural element.

The derailment load shall be assumed to act anywhere on the deck not physically restricted. Where tracks are protected by guardrails, the maximum excursion due to derailment shall be limited to that allowed by the placement of guardrails.

Guardrails are typically placed one foot away from the inner face of the rail. Consult with the MOW Division for specific guardrail placement.

A separate check for slab punching shear associated with the derailment shall be performed. The punching shear check shall consist of an equivalent static wheel load with applicable impact factor distributed over an area of one square foot.

When checking any component of the superstructure or substructure that supports two or more tracks, only one train on one track shall be considered to have derailed, with the other track(s) each loaded with a stationary train. No impact allowance shall be considered for the stationary train on the other track(s).

All elements of the structure shall be checked assuming simultaneous application of all derailed wheel loads. The reduction of positive moment in continuous slabs due to derailed wheel loads in adjacent spans shall not be allowed.

4.4. Pedestrian Loads (PL)

4.4.1. Safety Walks

Safety walks (walkways) are required on both sides of the transit line structures and are meant for use by maintenance personnel with light equipment and as emergency egress for passengers. Waiver of this requirement must be approved in writing by the Authority. The pedestrian load for such safety walks is 85 psf uniform loading or a concentrated load of 350 lbs, whichever is critical.

Where off-track equipment may be driven on the walkway, design shall consider appropriate wheel loads. Consult with MOW Division and Subway Operations Department of the MBTA for weight and configuration of equipment.

4.4.2. Pedestrian Areas

The station platforms, pedestrian ramps, mezzanines, and other pedestrian areas shall be designed for a uniform load of 150 psf or a uniform load of 100 psf and a concentrated load of 300 lbs. The concentrated load shall be positioned in the location that produces the maximum effect.

Pedestrian areas expected to be subjected to maintenance vehicles shall be designed for such loads or pedestrian loads whichever is critical.

4.4.3. Stairways

Stairways shall be designed for a uniform load of 150 psf or a uniform load of 100 psf and a concentrated load of 300 lbs on the center of stair treads, whichever is critical.

4.4.4. Railings

4.4.4.1. Platform Railings

Railings and barriers around stairways, stairwells, and balconies along station platforms shall be designed for a horizontal load of 150 plf and a vertical load of 100 plf applied simultaneously at the top of railing. Horizontal members other than the top member in a multi horizontal rail member system shall be designed for a horizontal load of 50 plf and a vertical load of 50 plf applied simultaneously at each horizontal member. Posts shall be designed for a transverse load equal to 150 plf times the spacing between the posts. Load shall be applied 5 ft maximum above the walkway.

4.4.4.2. Transit Bridge Railings

Transit bridge railings and their connections to supporting structures outside the areas specified in Section 4.4.4.1 shall be designed for a Transverse load of 50 plf and a vertical load of 50 plf applied simultaneously at each horizontal member. Posts shall be designed for a transverse load equal to 50 plf times the spacing between the posts. Load shall be applied 5 ft maximum above the walkway.

In addition to loads specified in Section 4.4.4.1 and 4.4.4.2, members and posts shall be designed for a single load of 200 lbs applied either laterally or vertically at any point along the handrail. Posts shall be designed for a single load of 200 lbs applied either laterally or vertically, at the point of attachment of the top railing.

4.4.4.3. Work Area Railings

Railings in work areas and equipment rooms shall be designed for a uniform load of 200 plf applied either laterally or vertically at any point along the handrail.

4.4.4.4. Other Railings

Railings in other places of public assembly shall be designed as per the latest edition of the Massachusetts State Building Code.

4.5. Wind Load

4.5.1. Wind Load on Structure (W)

The aerial structures shall be designed to withstand wind loads of uniform pressure acting on the superstructure, the substructure and the live loading as specified herein. Wind loading on the various system elements, such as signalization and communication equipments, and all other fixtures on the structure shall be considered in the design of both superstructure and substructure. The magnitude and location of wind loads on system elements shall be determined by the consulting structural engineer after consulting the MBTA Maintenance of Way Division (MOW) and Power Division with regard to specific configuration of the elements used by the MBTA. As a minimum, wind load on structure shall comply with AASHTO Bridges unless otherwise

directed by the Authority.

4.5.2. Wind load on Live Load (WL)

Design shall include a simultaneously applied transverse horizontal wind load of 320 plf and a longitudinal horizontal wind load of 80 plf for the entire length of track supported by the element being designed. The transverse loads shall be applied to the train as concentrated loads at the axle locations, in a plane 7.0 feet above the top of low rail and normal to the track. Consult with the Authority for the height of the transverse force above the track for a specific train type.

The longitudinal force shall be applied to the rails and superstructure as a uniformly distributed load over the length of the train in a horizontal plane at the top of rail. The horizontal force component transmitted to the rails and superstructure by an axle shall be concentrated at the rail having direct wheel-flange-to-rail-head contact.

These loads apply to the design of superstructure and substructure elements supporting a single track. For the design of substructure elements supporting two or more tracks, these loads shall be increased by 30% when two or more tracks are loaded; this factor accounts fully for shielding effect of vehicle-on-vehicle as the two trains run alongside each other.

4.6. Earth Pressure (E)

Substructure elements shall be proportioned to withstand lateral earth pressure in accordance with the provisions provided in the geotechnical information and as stipulated by the geotechnical engineer. The effects of construction procedures on the development of lateral earth pressures shall be considered. Short term construction conditions as well as long term loading conditions shall be considered for the design. In general, the following guidelines shall be adhered to:

- The design unit weight of earth, above the ground water table, shall be not less than 130 pcf. A submerged unit weight of not less than 68 pcf shall be used for earth below the ground water table. These values shall be used for calculating the loads on the structure.
- Structures that retain earth shall be designed for earth pressure due to earth abutting against the structure and load surcharges imposed on abutting earth. Consideration shall be given to multi-layered effects where substantial differences in soil properties occur over the depth of the structure. Allowances shall be made for both dry and submerged earth pressure and for hydrostatic pressure, depending on the location of the water table.
- The permanent horizontal loads on structures shall be computed using the at-rest earth pressure coefficient, K_0 and distributing the pressure in the triangular form. The at-rest should be considered as the design earth pressure unless specific structure and site condition permit otherwise.
- Live loads and dead loads from adjacent buildings shall be considered in computing horizontal pressure.

- Where transit or railroad loading occurs, the surcharge shall be calculated using AREMA criteria.
- Resistance from passive earth pressure acting against the front face of a wall shall be neglected when computing the factors of safety against sliding and overturning.
- Unbalanced earth pressure condition on sides of the structures should be taken in consideration especially during construction or in future excavation or backfilling.
- The design bearing pressures and foundation elevations to be used in the design of foundations shall be established in consultation with the geotechnical engineer. The maximum design soil bearing pressure and allowable soil bearing pressure and foundation elevations shall be shown on the substructure plans.

4.7. Hydrostatic Pressure and Buoyancy (B)

The effects of hydrostatic pressure and buoyancy shall be considered whenever the presence of groundwater is indicated. Hydrostatic pressures for ground water and seawater shall be computed at 62.4 pcf and 64 pcf, respectively, per feet of depth below the water table.

During construction and backfill operations, the elevation of groundwater shall be observed and controlled so that the calculated total weight of structure and backfill shall always exceed the calculated uplift due to buoyancy by at least 50%. The possibility of future significant changes in groundwater elevation shall be considered in the design. Adequate resistance to floatation, for full uplift pressure on the structure foundation, based on maximum possible height of water shall be provided neglecting sidewall soil friction effects.

The backfill shall be considered as the volume contained within the vertical planes defined by the outer limits of the structure. For buoyancy calculations, the actual unit weight of backfill placed over the structure shall be used, but shall not be taken as more than 120 pcf. Where full hydrostatic pressure below the ground water table is used as a design load, a submerged unit weight of not more than 58 pcf shall be used for the earth below the ground water table.

The unit weight values established above could be modified based on utilizing specific fill materials approved by the Authority.

4.8. Stream Flow, Floating Ice, and Drift Condition (SF)

Local flooding may add load to structures spanning over waters or structures in the flood plain. Design of the structures should make allowance for this loading as required by the particular type of structure and the conditions affecting each location. Elevations of Boston Harbor tidal flooding and Charles River Basin water surfaces as well as other rivers flood information shall be retrieved from the official flood records and used in the design.

Where ice is anticipated, the thickness of ice and the height at which it applies shall be

determined by investigation at the site of the structure and its effects on the structure shall be determined.

All piers and other portions of structures that are subject to flood forces, floating ice or drift shall be designed in accordance with sound engineering practice. The requirements outlined in AASHTO Bridges shall be used as a guide.

Design shall take into consideration potential for scour and foundations shall be designed for worst scour conditions unless scour countermeasures are in place as part of the proposed design.

4.9. Snow Load (SN)

An allowance of 30 psf for snow and ice loading shall be included on all live load or on closed-deck type superstructure whichever is worst. The snow load on safety walks shall not be less than 30 psf.

4.9.1. Snow on Canopies, Roofs, and Platforms

Canopies, roofs, and platforms shall be designed for snow loads, snowdrift, and ponding in accordance with the latest edition of the Massachusetts State Building Code. For new designs or evaluation of existing structures, the snow load shall not be less than 30 psf.

4.10. Thermal Force (T)

Provisions shall be made for deformations and stresses resulting from temperature variations. In addition, thermal gradient within the section of the structure shall be taken into consideration.

The expected temperature rise and fall shall be assumed as follows:

- Concrete
 - Temperature Rise 35 Deg F
 - Temperature Fall 45 Deg F
 - Coefficient of Expansion 0.0000060 inch/inch/ Deg F

- Steel
 - Temperature Rise 70* Deg F
 - Temperature Fall 100* Deg F
 - Coefficient of Expansion 0.0000065 inch/inch/ Deg F

- Rail
 - Temperature Rise 70 Deg F
 - Temperature Fall 80 Deg F
 - Coefficient of Expansion 0.0000065 inch/inch/ Deg F

* The thermal movement range was adapted from Massachusetts Highway Department Bridge Manual for temperature rise above 50° F base value and fall below 68° F base value. This would allow for the erection of steel structures within an ambient temperature range of 50 and 70 Deg. F.

Base temperature for structures shall be assumed 68 degrees (F). Consult with MOW Division for base temperature for continuous welded rail installation.

4.11. Rail/Structure Interaction Force

The design of the structural elements shall include the forces resulting from the interaction between rail and structure in non-ballasted aerial structures. No interaction loads need to be considered for ballasted structures.

The interaction forces are typically due to thermal variations between the rail and the deck. The rail fasteners would mobilize longitudinal and radial forces (on curved rail) resisting the differential movement between the deck and the rail. The design shall include the loads mobilized in the structure that provides longitudinal and lateral restraint to the rail (when the structure is located on a curve). The analysis shall be based on the maximum differential temperature in the rails. Thermal rail/structure interaction investigation shall include the entire structure (from abutment to abutment) and a minimum 200 feet of tracks beyond each abutment.

When the interaction force becomes the governing force and its load combination is resulting in excessive design sections, a refined analysis shall be performed to account for the actual interaction between the structure and the rail.

Termination of continuous welded rails (CWR) on a structure should be avoided. Thermal forces that develop due to the restraint of CWR shall be considered as a temperature load.

With direct fixation track, provision shall be made for transverse and longitudinal forces due to temperature variation in both the CWR and the structure. These forces shall be applied in a horizontal plane at the top of the rail.

4.11.1. Rail Transverse Force (RT)

Rail Transverse Force (for structures supporting horizontally curved track) shall be considered as follows:

4.11.1.1. For equal adjacent spans

The transverse force per span of structure per rail (measured in kips) shall be determined by the following formula:

$$RT = 2000 E A \alpha \Delta T \sin 1/2 (L/R \times 180/\pi)$$

Where:

E = Young's modulus of rail, ksi

A = Rail cross sectional area, in²

α = Coefficient of expansion of rail, inch/inch/degree (F)

ΔT = Temperature differential in degrees (F)**

L = Span length along curve, ft
R = Curve radius, ft

** Taking into consideration rail installation temperature, present rail temperature, ambient temperature, and the temperature of the structure.

4.11.1.2. For unequal spans

The transverse force must be resolved into components parallel and perpendicular to the pier at each rail fastener and summed.

4.11.2. Rail Longitudinal Force (RL)

Rail Longitudinal Force: The longitudinal force per structure per rail shall be determined by the following formula:

$$RL = F \times L$$

Where

F = Restraining force (maximum prior to slippage) of rail fastener per foot.
The recommended load for fastener is in the range of 2200 pounds to 3200 pounds.

L = Average span length of two adjacent spans in feet. For curved tracks, L is measured along the curve.

RL = The total force, shall not exceed the maximum restraining force per rail.

It is recommended that the direct fixation fasteners with satisfactory in-service performance history be installed. In lieu of in-service performance history, new direct fixation fasteners that have satisfactorily passed extensive laboratory testing may be used.

The type of fasteners shall be pre approved by the MBTA Maintenance of Way Division.

4.11.3. Rail Break Force (RB)

For direct fixation track, provision shall be made for longitudinal forces due to a rail break. Forces from a single broken rail at any one time shall be applied to the structure. Longitudinal break force shall be based on the maximum temperature differential in the rail. The mobilized forces in the structure are equal to the maximum restraint force in fasteners of the broken rail until the thermal force is equalized. The maximum allowable longitudinal gap in a rail due to rail break shall be 2 inches.

The structure shall be designed to include horizontal forces at the fixed bearing due to the summation of each rail fastener's longitudinal restraint. The structure shall also be designed to include a twisting moment in a horizontal plane at the height of the low rail due to opposing directions of forces in the broken and unbroken rails.

4.12. Shrinkage and Creep Force (S)

Stresses and movements resulting from concrete shrinkage and creep shall be considered in the design and included in the specified load combinations. The shrinkage coefficient shall be assumed to be 0.0002 inches per inch for both prestressed and reinforced normal weight concrete. Shrinkage coefficient for lightweight concrete shall be determined for the type of lightweight aggregate used.

4.13. Collision Load

Substructure elements that are situated less than 10 feet from the edge of an adjacent street or highway shall be designed to withstand a horizontal static force of 225 kips, unless protected with suitable barriers. This force is to be applied on the support element at an angle of 10 degrees from the direction of road traffic and at a height of 4 feet above ground level. This condition occurs with the dead load of the structure but need not to be applied concurrently with other loadings.

Substructure elements that are situated along railroad tracks shall be protected in accordance with AREMA.

4.14. Earthquake Forces (EQ)

The seismic design of structures supporting transit vehicles shall be in accordance with Seismic Design of AASHTO Bridges, using the following parameters unless otherwise directed by the Authority:

Acceleration Coefficient	A	= 0.17
Seismic Performance Category	SPC	= B (AASHTO definition)
Important classification	IC	= I

Site coefficient shall be determined by the design geotechnical engineer.

When utilizing the response modification factors, the design of foundation shall utilize the upper limits of the superstructure and substructure material strength and the normal limits of the foundation materials.

4.15. Loads on Storage and Machinery Rooms

Unless actual equipment loads are known, electrical and signal equipment rooms, pump rooms, service rooms, storage spaces and machinery rooms and access areas shall be designed for a uniform load of 250 psf.

4.16. Loads on Gratings

Subway emergency exit covers and ventilation shaft gratings in roadway areas shall be designed for HS 25 (AASHTO HS20-44 multiplied by a factor of 1.25) loading with impact. Gratings in medians or sidewalks or areas surrounded by curbs less than 12 inches in height shall be designed for HS 25-44 loading without impact and allowing 50% overstress for occasional application of wheel loads. Gratings surrounded by parapet walls 12 in. or greater in height and grating in subway shall be designed for a uniform load of 200 psf.

4.17. Loads on Earth Retaining Structures

Where applicable, the loads and forces listed in Section 4 shall be used for the design of earth retaining structures supporting transit loadings. The effects of surcharge loads from adjacent buildings, live, dead, snow loads, etc shall be considered in the design. For earth retaining structures constructed under or adjacent to vacant property, consideration shall be given to possible future use of the property as directed by the Authority.

4.18. Loads on Culverts

Where applicable, the loads and forces listed in Section 4 shall be used for the design of culverts carrying transit loadings. The effects of loads from adjacent buildings, live, dead, snow loads, etc carried on foundations within the zone of influence shall be considered in the design. For culverts constructed under or adjacent to vacant property, consideration shall be given to possible future use of the property as directed by the Authority.

5. Loading Combinations

5.1. Strength Requirement (Load Factor Design)

The minimum strength required for structural members and their connections supporting the transit loading shall be computed from the most critical group listed below.

Group I $1.30 \{ \beta_D DL + 1.67(LL + I + RF) + \beta_P PL + (CF \text{ or } NF) + \beta_E E + B + SF + RT + RL \}$

Group IA $1.30 \{ \beta_D DL + 1.25(LL + I + RF) + \beta_P PL + (CF \text{ or } NF) \}$ (Extra-Ordinary-Car consist
or using maintenance work cars
combined with revenue cars)

Group II $1.30 (\beta_D DL + \beta_E E + B + SF + RT + RL + W + S + T)$

Group III $1.30 (\beta_D DL + (LL + I + RF) + \beta_P PL + (CF \text{ or } NF) + \beta_E E + B + SF + RT + RL + 0.3W + WL + LF)$

Group IV $1.25 \{ \beta_D DL + (LL + I + RF) + (CF \text{ or } NF) + \beta_E E + B + SF + S + T + RT + RL +$

$$0.3W + WL + LF + SN\}$$

- Group V $1.30 (\beta_D DL + \beta_E E + B + SF + LF + 0.85 DR)$
- Group VI $1.30 (\beta_D DL + 0.85 RB)$
- Group VII Seismic load combinations shall be in accordance with AASHTO Bridges with the addition of live load (with no impact) equal to the effect of a fully loaded stationary train on one track only.

5.2. Service Requirement (Allowable Stress Design)

For the serviceability and durability checks involving fatigue, deflection, cracking, and vibration, and for the design of structure components requiring Allowable Stress (working stress) analysis, the loads shall be computed from the most critical group listed below:

Group Loading	Allowable Basic Unit Stress
Group I $DL + (LL + I + RF) + \beta_P PL + (CF \text{ or } NF) + \beta_E E + B + SF + RT + RL$	100%
Group IA $DL + (LL + I + RF) + \beta_P PL + (CF \text{ or } NF)$ (Extra-Ordinary-Car consist or using maintenance work cars combined with revenue cars)	140%
Group II $DL + E + B + SF + RT + RL + W + S + T$	140%
Group III $DL + (LL + I + RF) + \beta_P PL + (CF \text{ or } NF) + \beta_E E + B + SF + RT + RL + 0.3W + WL + LF$	125%
Group IV $DL + (LL + I + RF) + (CF \text{ or } NF) + \beta_E E + B + SF + S + T + RT + RL + 0.3W + WL + LF + SN$	133%
Group V $DL + \beta_E E + B + SF + LF + 0.85 DR$	125%
Group VI $DL + RB$	125%
Group VII Seismic load combinations shall be in accordance with AASHTO Bridges with the addition of live load (with no impact) equal to the effect of a fully loaded stationary train on one track only.	

Where

- DL Dead Load
 LL Vehicle Live Load
 I Vehicle Impact Load

CF	Centrifugal Force
DR	Derailment Load
RF	Rolling Force
LF	Longitudinal Breaking and Tractive Force
E	Earth Pressure
B	Hydrostatic pressure and Buoyancy
W	Wind Load
WL	Wind Load on Live Load
SN	Snow and Ice load on Live Load
SF	Stream Flow pressure and Flooding
S	Shrinkage and Creep forces
T	Thermal force
RB	Rail Break
PL	Pedestrian Load
NF	Nosing force
RT	Rail Transverse Force
RL	Rail Longitudinal Force
β_P	Equals 1.0 at station platforms, 0.5 at safety walks for Group I and 1.0 for safety walks for Group IA.
β_D, β_E	Shall be in accordance with AASHTO Bridges.

6. Special Design Considerations

6.1. Stray Current

Consideration shall be given to the potential presence of stray current and its effect on the structural elements. Structures shall be evaluated assuming the presence of the stray current unless field test proves otherwise. Protection of structure against the stray current shall be incorporated in the structure documents including the life expectancy of any isolating or sacrificial materials when used

6.2. Camber and Deflections

As a guide in design, the long term predicted camber growth, less deflection due to full dead load, shall be limited to 1/2000 of span length.

Girders of simple or continuous spans shall be designed so that the deflections due to live load plus impact do not exceed 1/1000 of the span length. The deflection of cantilever arms due to live load plus impact shall be limited to 1/375 of the cantilever arm.

6.3. Vibration Limitations

To limit potential dynamic interaction between aerial structures and transit vehicles, the aerial structures shall be designed such that the unloaded natural frequency of the first mode of vibration of the longitudinal girders is not less than 2.5 cycles per second. Further, not more than one span in a series of three consecutive spans shall have the first mode of frequency less than 3.0 cycles per second.

Long simple spans having low natural frequencies may be used, provided that due consideration is given to possible vibrational interactions between the structure and the vehicle, and their effect on vertical impact loading.

6.4. Fatigue

Consideration shall be given to the effect of change of stress levels caused by the passage of transit vehicles over the structures. Over the life of the structure, 3.0 million cycles of maximum stress shall be used in estimating the number of repetitive maximum stress cycles.

6.5. Uplift

Provisions for uplift shall comply with ASSHTO Bridges

6.6. Jacking

End diaphragms shall be designed for a jacking force equal to the dead load end reaction of the adjacent primary structural member to facilitate bearing replacement. The diaphragm design shall consider the eccentricity associated with the jack location.

6.7. Construction Loads

Provision for construction loads shall comply with AASHTO Bridges and as directed by the Authority.

7. Bearings

The design and construction of bearings shall be in accordance with the AASHTO Bridges requirements.

The force due to friction at expansion bearings or shear resistance at elastomeric bearings shall be considered in the design.

8. Foundations

8.1. General

The foundations of all bridges and aerial structures supporting transit vehicles shall be designed such that the maximum post construction settlement at any pier or abutment foundation will not cause a combined change of gradient for any two adjacent spans to exceed 0.1 percent.

8.2. Soil Data

Any geotechnical input to design shall be based upon geotechnical data derived from the subsurface investigation programs and shall commensurate with the corresponding design level. Subsurface investigation for conceptual/preliminary design and final design, in general, shall provide information such as: ground water levels, soil and rock unit weights, bearing capacity under normal and seismic conditions, angle of internal friction, coefficient of active, passive and at-rest pressures, swelling potential, modulus of elasticity, Poisson's ratio, compressive and tensile strengths, shear strengths, consolidation, liquefaction potential, pH, resistivity and chemical properties, etc. Other routine tests shall include grain size, Atterberg Limits, and moisture content.

The investigation in support of conceptual/preliminary design may be based upon limited testing, whereas the investigation in support of final design shall provide more detailed site specific information.

All obtained geotechnical information shall be made available to the construction bidders by including the information in the bidding documents or by referencing the availability of the geotechnical information and Geotechnical Report.

The applicable Geotechnical Report shall define the soil properties to be used in design, including densities, strengths, deformity and permeability. The report shall also include recommendations for earth pressure coefficients, allowable bearing capacities, allowable skin friction values, foundation types, settlement estimates, seismic characteristics and construction methods where applicable.

The Geotechnical Report shall also, define the scour assessment and counter measures, type and limits of scour countermeasures, and construction methods where applicable. Calculations and details must be based on a hydraulic study and subsurface information of the river or tidal area.

Actual soil data derived from structure site specific geotechnical exploration, sampling and testing shall be included in the Geotechnical Report.

Foundation design shall take into account the presence of potentially detrimental substances in soils, if any, such as chlorides and sulfates. This may be accomplished by providing appropriate protection for reinforcement, concrete, and metal embedments.

8.3. Applications

Shallow foundations may be used where there is a suitable bearing stratum near the surface, where there are no highly compressible layers below and where the calculated settlements are acceptable. Where the bearing stratum at ground surface is underlain by weak and compressible materials, the use of deep foundations shall be given consideration.

Deep foundation systems such as pile, drilled shafts, etc. shall also be used where there is a potential for scour, erosion or settlement, even though the bearing capacity of the soil may be sufficient to make the use of shallow foundations feasible.

8.3.1. Shallow Foundations

Shallow foundations include spread footings, combined footings to support load from more than one structural unit, strip footings for walls, and mats and rafts beneath the entire structure area.

The design bearing pressure shall be provided in the geotechnical report and on the abutment/retaining wall elevation drawings. All footings shall be designed to keep maximum soil pressures within safe bearing values. In order to prevent undesirable settlement, footings shall be designed to keep the pressures under long term sustained loads as nearly uniform as practicable. Uplift of edges or corners will not be permitted when using service load design. Eccentricity of the resultant force shall not exceed $\frac{1}{4} B$ (width of footing) in load factor design. Guideline set forth in AASHTO bridges shall govern the seismic design.

8.3.2. Deep Foundations

Piles may be either bored or driven. The geotechnical report shall provide information relative to foundation materials and other field conditions in connection with pile driving and shall provide recommendations as to the types and lengths of piles, which will be most suitable for use under these conditions. Specific noise and vibration limits shall be established to conform to local requirements.

Pile footings shall be designed such that the load on any pile does not exceed its allowable service load, with the applied load being adjusted to reflect the allowable percentage of basic unit stress for various load combinations given in Section 5.2 of these Guide Specifications.

Static and dynamic analysis and design of piles and drilled shafts shall comply with the requirements of AASHTO Bridges.

8.4. Deformation and Settlement

Deformations of the structure, including foundation settlement, shall be kept to a minimum, not only for their effect on structural behavior, but also for their effect on track maintenance. Loads induced on structures by a tolerable differential settlement shall be considered in the design.

The differential settlement between two adjacent aerial structure piers shall not exceed 1/1500 times the sum of the length of any two adjacent spans nor settlement limits specified in Section 8.1.

9. Design

9.1. Axle Load Distribution

Axle loads on track ties, or on direct fixation rail fasteners containing elastomeric material, for concrete, steel, and timber structures shall be considered to be uniformly distributed, both in the lateral and longitudinal directions, as per requirements stated herein. For additional information, refer to AREMA code for each type of structure in consideration.

9.1.1. Axle Load Distribution Earth Retaining Structures

Surcharge due to axle loads shall be in accordance with AREMA with project design axle load.

9.1.2. Axle Load Distribution Culverts

Distribution of axle loads shall be in accordance with AREMA with project design axle load.

9.2. Concrete Design

Design and detailing shall comply with AASHTO Bridges except as modified in these guide specifications and as directed by the Authority

9.2.1. Material

- Unless otherwise specified, all cast-in-place concrete shall have a minimum specified compressive strength of 4000 psi at 28 days. Cast-in-place concrete for bridge decks shall have a minimum specified compressive strength of 4500 psi at 28 days.
- High Performance Concrete (HPC) maybe used when feasible and as approved by the Authority.
- Reinforcement including ties and spirals shall conform to ASTM A615 Grade 60 requirements. Epoxy coated bars, if specified, shall satisfy the requirement in ASTM A775 except where specifically noted otherwise.
- Concrete mix design must be pre-approved by the Authority.

9.2.2. Axle Load Distribution

- For ballasted deck, the axle loads shall be assumed as uniformly distributed
 - a) Longitudinally over a 3 foot length of rail plus the depth of ballast under the tie, plus twice the effective depth of slab, limited, however, by the axle spacing
 - b) Laterally over the length of tie plus the depth of ballast but not greater than the width at the bottom of ballast.

- For non-ballasted deck, the axle loads may be assumed as uniformly distributed –
 - a) Longitudinally over a length of 3 feet.
 - b) Laterally over the width of rail fastener plus twice the depth of deck.

- For the design of longitudinal beams, no longitudinal distribution of concentrated wheel loads shall be used.

9.2.3. Reinforcement details

Comply with AASHTO Bridges except as modified in these Guide Specifications and as directed by the Authority.

9.2.4. Crack Control

The provision for controlling flexural cracking as described in the AASHTO Bridges shall apply for all structures. In addition, the reinforcing steel in the exterior face of concrete members in contact with the ground shall not exceed bar size designation # 11.

9.2.5. Corrosion Protection

Corrosion monitoring shall be provided for all structures. Calcium nitrite corrosion inhibitor shall be added to the concrete. Submerged steel surfaces shall be protected cathodically.

9.2.6. Shrinkage and Creep

To control shrinkage stresses in concrete slabs and walls and to minimize cracking, contraction and expansion joints shall be provided at spacing preferably not exceeding that specified in MHD design standards. Joint spacing shall not exceed the spacing values specified in AASHTO Bridges. All construction joints shall have continuous reinforcing steel, and keys or other positive means of shear transfer. In all exterior elements in contact with soil, joints shall have non-metallic water stops.

9.3. Prestressed Concrete Design

Provisions in Section 9.2 shall apply and the following:

Design and detailing shall comply with AASHTO and PCI specifications and MHD Bridge Manual except as modified in these guide specifications and as directed by the Authority.

9.3.1. Material

- Unless otherwise specified, concrete for prestressed members shall have a minimum compressive strength of 6000 psi at 28 days, and a minimum compressive strength at the time of initial prestress of 4000 psi.
- High Strength Concrete may be used when feasible and as approved by the Authority.
- Prestressing reinforcement shall be high strength steel wire (ASTM A421), high strength strand wire (ASTM A416, Grade 270) or high strength alloy bars (ASTM A722).

9.3.2. Shrinkage and Creep

Provisions in Section 9.2.6 shall apply and the following: To minimize creep problems, it is suggested that the average prestressing compression stress after losses shall not exceed 1000 psi.

9.4. Steel Design

Design and detailing shall comply with AASHTO Bridges except as modified in these guide specifications and as directed by the Authority.

9.4.1. Material

- Unless otherwise specified, all structural steel shall conform to ASTM Standard Specification A709, Grade 50 and 50W.
- High strength bolts for structural steel connections, including suitable nuts and washers, shall conform to ASTM A-325 and anchor bolts shall conform to ASTM A-307.
- High Performance Steel (HPS) maybe used when feasible and as approved by the Authority. ASTM A709, Grade 100 and 100W may not be considered without written approval by the Authority.
- Every care should be taken to insure that dissimilar materials will not cause accelerated deterioration to the structure. Provisions to avoid contact between dissimilar materials should be established. Otherwise, connections and contact surfaces shall be thoroughly studied and detailed. Connections and details with proven history of success shall be used. New and unconventional details maybe used with the approval of the Authority.
- Old Materials shall be sampled and tested unless there is a satisfactory record of type of material and date of fabrication. At a minimum, old material shall be compared to AISC "Iron and Steel Beams 1873 to 1952".

9.4.2. Axle Load Distribution

- For ballasted deck, the axle loads shall be assumed as uniformly distributed
 - a) Longitudinally over a length of 3 feet plus the minimum distance from the bottom of

tie to the top of beams or girders, but not to exceed 5.0 feet nor the axle spacing
b) Laterally over a width equal to the length of tie plus the minimum distance from the bottom of tie to the top of beams or girders.

- For open deck structures, the tie shall be designed on the assumption that the maximum wheel load, without impact, on each rail is distributed equally to all ties or fractions thereof within a length of 4.0 feet, but not to exceed 3 ties.
- For the design of longitudinal beams and girders, the wheel load shall be considered as a series of concentrated loads for design purposes and no longitudinal distribution of loads shall be used.
- For the design of transverse beams supporting ballasted deck without stringers, the portion of the maximum axle load on each beam shall be equal to $P = 1.15AD/S$ where A is the axle load, D is the effective beam spacing and S is the axle spacing in feet, see AREMA for values of D. The load P shall be applied, as two equal concentrated loads on each beam at each rail, equal to $P/2$. No lateral distribution of such loads shall be assumed. Rigorous analysis maybe made if higher accuracy is required.

9.5. Aluminum Design

Design and detailing shall comply with AASHTO Bridges except as modified in these guide specifications and as directed by the Authority.

9.6. Timber Design

Design and detailing shall comply with AREMA specifications except as modified in these guide specifications and as directed by the Authority

9.6.1. Material

Timber shall be in accordance with the provisions of AREMA code, using the appropriate allowable stresses.

9.6.2. Axle Load Distribution

Provisions of distribution of axle loads on track ties for timber structures shall be in accordance with AREMA code.

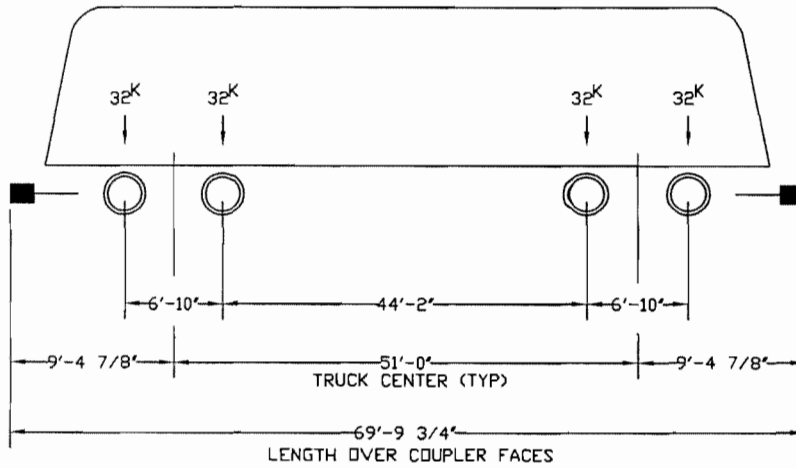
9.7. Masonry Design

Design and detailing shall comply with AREMA specifications except as modified in these guide specifications and as directed by the Authority

9.7.1. Material

- Concrete masonry units shall meet the requirement of ASTM C145 and C90, Grade N, Type 1, normal weight and shall have a minimum compressive strength of 2000 psi on the net-bedded area.
- Mortar shall meet the requirements of ASTM C270, Type N above grade and Type M below grade.
- Grout shall have a minimum compressive strength of 2500 psi at 28 days.

Appendix A



#3 RED LINE RAPID TRANSIT CAR

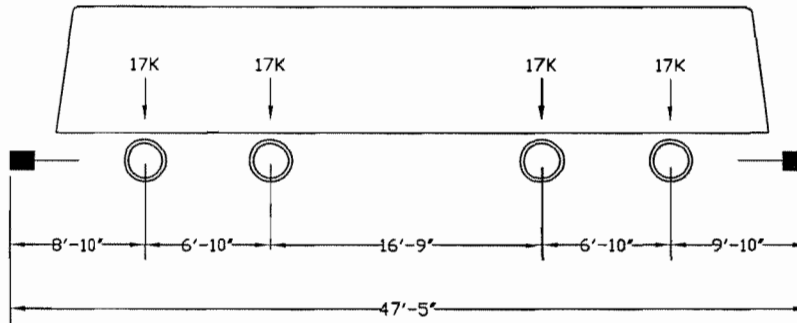
LOADINGS:

WEIGHT OF EMPTY CAR = 76,885 LBS

MAX. CRUSH LOAD = 42,935 LBS

ACTUAL WEIGHT OF FULLY LOADED CAR = 119,820 LBS

DESIGN LOAD FOR FULLY LOADED CAR = 128,000 LBS



PCC CAR - HIGH SPEED RED LINE

LOADINGS:

WEIGHT OF EMPTY CAR = 40,035 LBS

MAX CRUSH LOAD = 18,200 LBS

ACTUAL WEIGHT OF FULLY LOADED CAR = 58,235 LBS

DESIGN LOAD FOR FULLY LOADED CAR = 68,000 LBS



MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

STRUCTURAL DESIGN OF
TRANSIT AND LIGHT
RAIL STRUCTURES

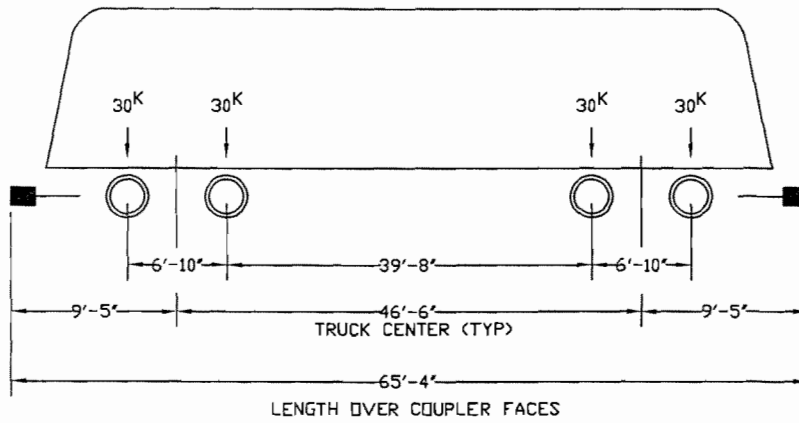
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Drawing No.:

FIG. 1

Scale: N.T.S

Gannett Fleming



#12 ORANGE LINE RAPID TRANSIT CAR

LOADINGS:

WEIGHT OF EMPTY CAR = 68,780 LBS

MAX. CRUSH LOAD = 34,720 LBS

ACTUAL WEIGHT OF FULLY LOADED CAR = 103,500 LBS

DESIGN LOAD FOR FULLY LOADED CAR = 120,000 LBS

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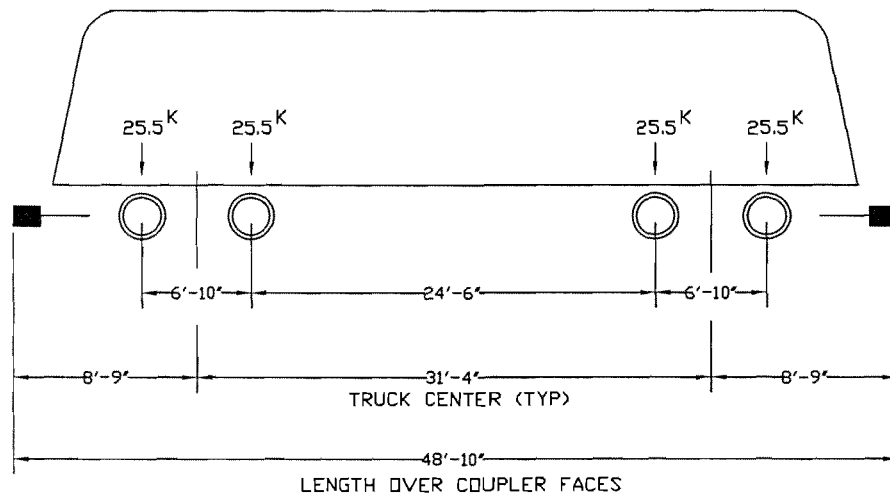
MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

STRUCTURAL DESIGN OF
TRANSIT AND LIGHT
RAIL STRUCTURES

Comm. EIO	Drawn EIO	Checked: MAK	Date: OCTOBER 2005
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Drawing No.:
FIG. 2

Scale: N.T.S.



#5 BLUE LINE RAPID TRANSIT CAR

LOADINGS:

EMPTY VEHICLE = 69,000 LBS

MAX. CRUSH LOAD = 22,630 LBS

TOTAL LOADED CAR = 91,630 LBS

DESIGN LOAD FOR FULLY LOADED CAR = 102,000 LBS



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RAIL STRUCTURES

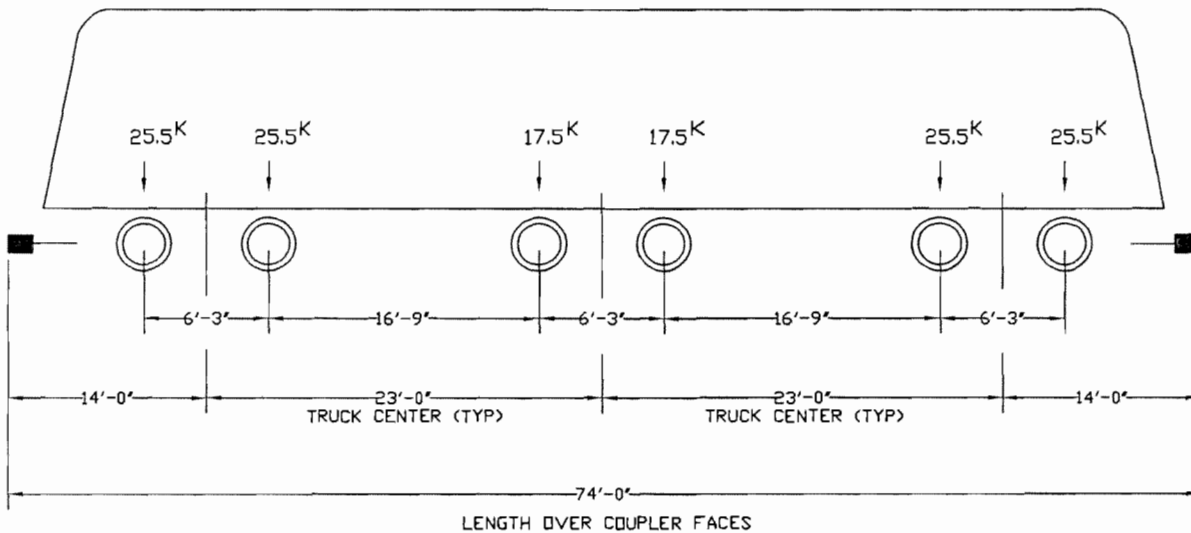
Drawing No.:

FIG. 3

Comm. EO	Drawn EO	Checked: MAK	Date: OCTOBER 2005
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Scale: N.T.S.

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#7 GREEN LINE LIGHT RAIL CAR

#7 CRS LIGHT RAIL CAR SHOULD ALSO BE USED ON THE HIGH SPEED RED LINE

LOADINGS:

WEIGHT OF EMPTY CAR = 85,500 LBS
 MAX. CRUSH LOAD = 41,580 LBS
 ACTUAL WEIGHT OF FULLY LOADED CAR = 127,080 LBS
 DESIGN LOAD FOR FULLY LOADED CAR = 137,000 LBS

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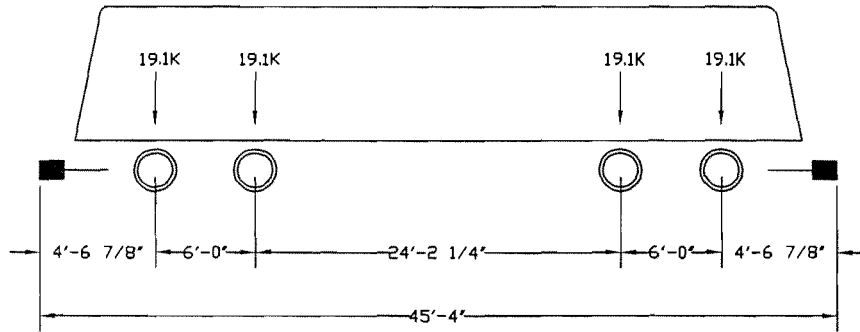
STRUCTURAL DESIGN OF
 TRANSIT AND LIGHT
 RAIL STRUCTURES

Comm. EIO	Drawn EIO	Checked: MAK	Date: SEPTEMBER 2005
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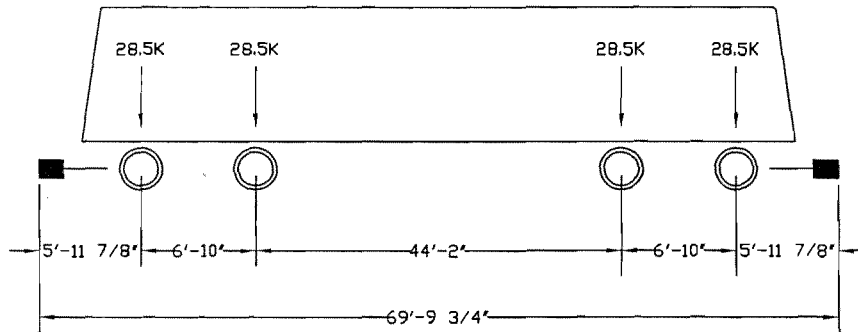
Drawing No.:
 FIG. 4

Scale: N.T.S.


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WORK CAR NO. 0526



WORK MOTOR CARS 01400



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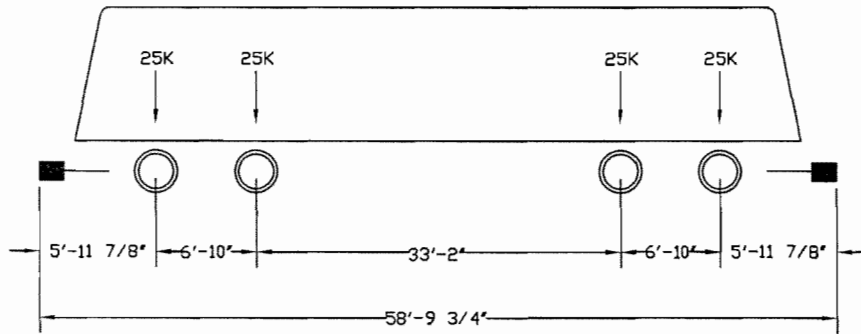
STRUCTURAL DESIGN OF
TRANSIT AND LIGHT
RAIL STRUCTURES

Comm.	EIO	Drawn	EIO	Checked:	MAK	Date:	SEPTEMBER 2005
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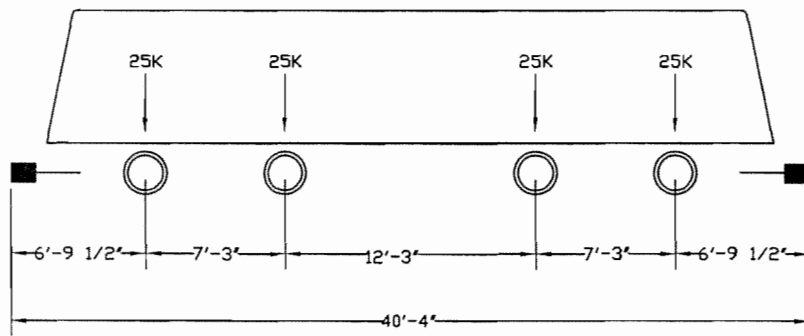
Drawing No.:
FIG. 5

Scale:
N.T.S

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WORK CAR NO. 04441



WORK CAR NO. 04443



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STRUCTURAL DESIGN OF
TRANSIT AND LIGHT
RAIL STRUCTURES

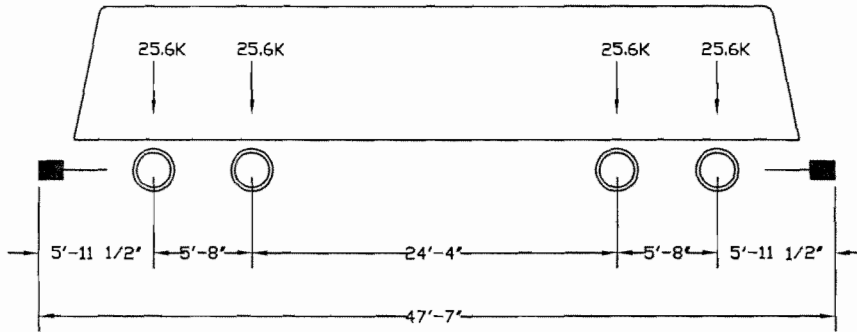
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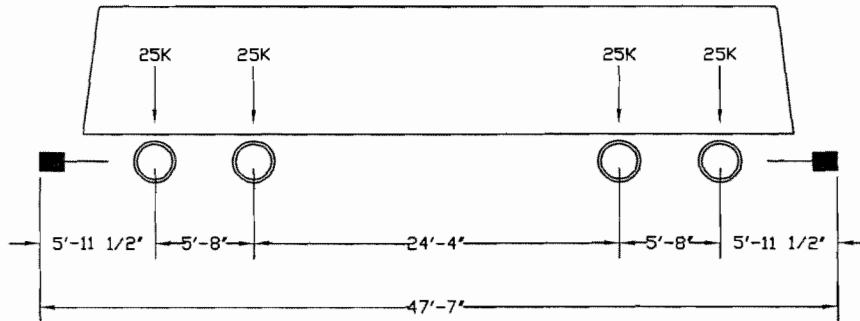
FIG. 6

Scale: N.T.S.

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Work Car No. 04446 & 04447



Work Car No. 04449



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RAIL STRUCTURES

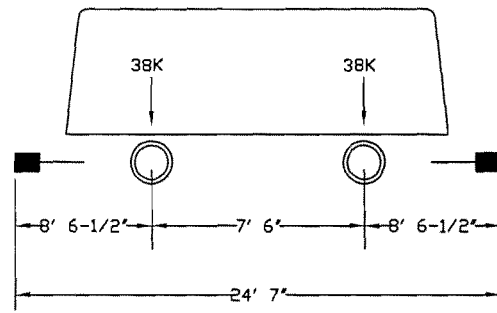
Comm.	EIO	Drawn	EIO	Checked:	MAK	Date:	OCTOBER 2005
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Drawing No.:

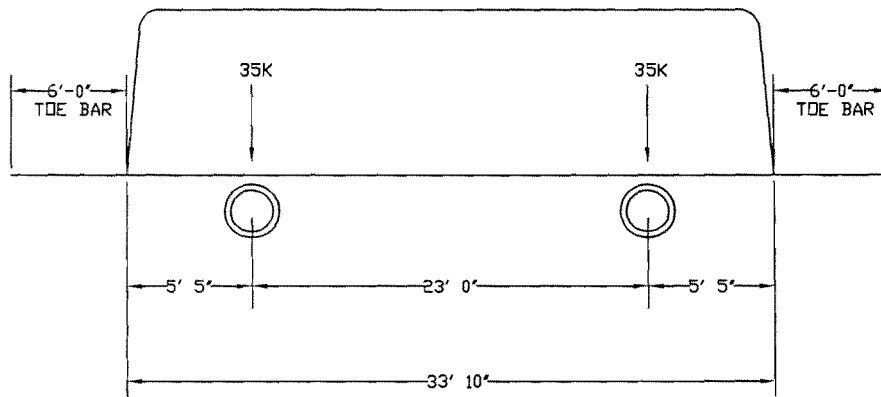
FIG. 7

Scale: N.T.S.

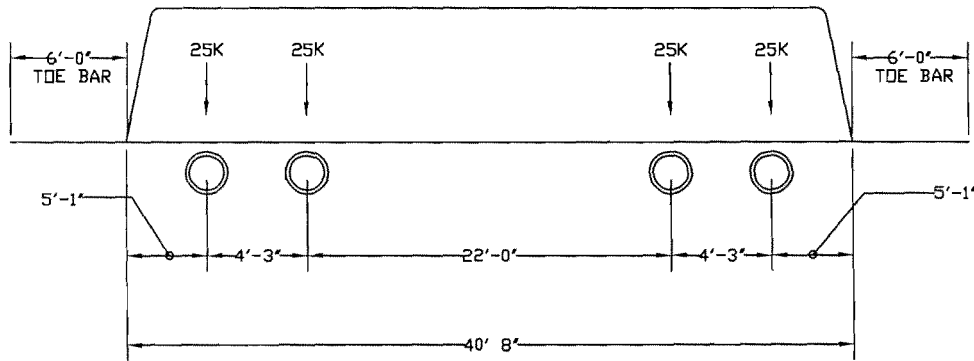
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Work Car - Ballast car



WORK CAR - TAMPER CAR



TAMPER CAR (50 TON)



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RAIL STRUCTURES

Drawing No.:

FIG. 8

Comm. EIO Drawn EIO Checked: MAK Date: OCTOBER 2005

Scale: N.T.S.