MASSACHUSETTS BAY TRANSPORTATION AUTHORITY

Maintenance of Way Division

Transit Design Standards Manual

(COMPANION PUBLICATION TO THE BOOK OF STANDARD TRACKWORK PLANS AND THE BOOK OF STANDARD TRACK MATERIAL/CONSTRUCTION SPECIFICATIONS)

SECTION 1

OUTLINE

A. Introduction

The Maintenance of Way Transit Design Standards is a three volume series that establishes design guidelines and criteria with respect to the material procurement required for, and construction of, MBTA Blue, Orange, Red (RTL) and Green (LRT) line track and related facilities. The three volume series is intended to supplement the MBTA Manual of Guidelines and Standards with respect to trackwork procurement and construction for MBTA Transit track facilities. Reference is made to the MBTA Manual of Guidelines and Standards within the M.O.W. Design Standards and any track facility design undertaking should be done with the Manual of Guidelines and Standards at hand. This three volume series is separate and distinct from the three volume Commuter Rail Design Standards.

B. Purpose

The Transit Design Standards were developed to provide guidance to Authority engineering staff, outside engineering consultants and equipment/material providers for track design and construction work at the MBTA. The M.O.W. Division endeavors to standardize design criteria to the greatest extent possible. Standardization of track components and material will be done wherever practical in an effort to limit the amount of spare parts inventory required and to simplify maintenance procedures.

As a 100+ year old transit agency, the MBTA's track system is built in tunnels dating to the late 19^{th} century, on elevated structures almost 100 years old, in city streets mixed with vehicular traffic or in reservations with extensive cross traffic and in dedicated rights-of-way through densely populated areas. As such, specific design requirements are varied. Consideration needs to be given to clearances, geometric constraints and constructablility in a confined area within a limited time window when designing track.

The design guidelines and criteria contained in the Transit Design Standards describe general performance requirements within established safety parameters. Specific design details will vary according to location, signal and/or power system conditions and civil constraints. Each project must be treated individually within the design framework described in the Standards. In many cases the best design input can be gained from previously developed successful designs and at least as importantly, from previously developed failed designs. Research into both failed and successful past design efforts is critical to the development of any new designs.

C. Design Standards Format

The M.O.W. Division Transit Design Standards are contained within this Manual, in the accompanying Book of Standard Trackwork Plans and Book of Standard Track Material and Construction Specifications. As the content of these documents is likely to change over time due to technological advances in track design and through experience, they are assembled to facilitate removal and replacement of individual pages.

D. Revisions

The revision number and date of issue are shown on each page of the Manual, the Book of Plans and the Book of Specifications. As revisions are made, pages are replaced, deleted or added and a new table of contents generated. Before beginning any design or material procurement effort, it must be determined that the latest issue of the documents is being used. This may be done through the Manager of Track Engineering in the M.O.W. Division.

E. Reference Sources

In addition to the Transit Design Standards Manual, Book of Standard Trackwork Plans and Book of Standard Track Material and Construction Specifications, the following reference sources may be required for material procurement and/or track design projects: 1) The Maintenance of Way Division's Track Maintenance and Safety Standards for the Blue, Orange and Red Lines, 2) Track Maintenance and Safety Standards for the Green Line and 3) The current edition of the AREMA Portfolio of Trackwork Plans and the Manual for Railway Engineering.

SECTION 2

GENERAL GUIDELINES

A. Purpose

The purpose of the Transit Design Standards Manual, Book of Standard Trackwork Plans and Material Specifications is to provide consistent criteria on track material procurement, trackwork design and track construction to outside design consultants, M.O.W. Division engineering staff, vendors and others.

The objective in providing this information is to ensure that the MBTA is building and maintaining a safe, efficient and reliable track system for the operation of RTL and LRT trains. It is in the interest of the MBTA, from a maintainability and spare parts inventory perspective, to standardize track design and construction practices to the greatest extent possible.

The Transit Design Standards Manual, Book of Standard Trackwork Plans and Material Specifications are to be used for the construction of new track facilities, the reconstruction of existing track facilities and for material procurement purposes for either new or reconstructed track. Criteria for the maintenance of existing track facilities are contained in the M.O.W. Division Track Maintenance Standards for RTL and LRT track.

Any track design work involving track facilities on the MBTA's Blue, Orange, Red and Green Lines will entail use of the Transit Design Standards Manual, Book of Standard Trackwork Plans and Material Specifications as a basis for design. Special circumstances and particular field situations may present conditions that are not addressed by the design documents. It is incumbent upon the designer in these cases to bring the situations/conditions to the attention of the Manager of Track Engineering who will provide direction. Of paramount concern is the safety of train passengers and MBTA employees.

B. Design Guidelines

Each of the MBTA's Rapid Transit Lines (RTL) and Light Rail Line (LRT) is a separate railroad with a captive fleet of rolling stock. As such, each line has specific design requirements that may or may not apply to any other line. This is especially true with the Green Line vs. the Blue, Orange and Red Lines. The Book of Standard Trackwork Plans contains references to RTL and LRT track that help distinguish the special requirements dictated by the differences in operating equipment on those lines. Many design elements are common to the different Rapid Transit Lines. However, due to different vehicle loads and clearance characteristics, not all elements are identical. These characteristics must be considered by the designer.

The following design guidelines and policies apply to all track facilities at the MBTA:

1. Safety – As previously stated, the primary focus of all engineering design shall be to provide a system in which trains will operate safely, reliably and efficiently and in which train passengers and MBTA personnel will be free from hazards.

2. Standardization/Reliability – Material procurement shall be in accordance with all applicable M.O.W. Division standards as directed by the design documents. Any departure from those standards will be at the sole discretion of the Manager of Track Engineering.

3. Clearances – Minimum horizontal and vertical clearances shall conform to those shown in the Book of Standard Plans for each line. Any deviation from the "suggested minimum" clearance shall only be done upon approval of the Manager of Track Engineering. The use of clearance cars and/or body side templates operated by M.O.W. engineering staff are required to confirm specific site clearances.

4. Design Loads – Track facilities shall be designed to accommodate the heaviest loaded vehicle that may operate on a particular line. That vehicle could possibly be a work car or other service vehicle. Specific information is available from the M.O.W. engineering staff. Bridges and other structures shall be designed for Cooper E-80 loadings as described in the AREMA Manual.

5. Design Speeds – Current maximum speed at any location on the MBTA system is 50 mph. Line speed for any given track segment is variable and is dependent on civil constraints, braking distance requirements, signal block layout, line of sight considerations and other factors. Site specific information is available from M.O.W. engineering staff.

SECTION 3

GEOMETRIC DESIGN CRITERIA

A. Horizontal and Vertical Survey Control Requirements

Horizontal control used to establish rectangular coordinates for track geometry shall be based on the Massachusetts Plane Coordinate System, Mainland Zone. Exceptions to this method will be at the discretion of the M.O.W. Division Manager of Track Engineering. Horizontal control points and supporting survey shall meet U.S. Coast and Geodetic Survey second order specifications for accuracy with Class II requirements (1 part in 20,000).

Vertical control shall be based on U.S. Coast and Geodetic Survey Mean Sea Level Datum, 1929 General Assessment. All vertical control points or benchmarks shall meet U.S. Coast and Geodetic Survey third order requirements for accuracy. Exceptions to this method will be at the discretion of the M.O.W. Division Manager of Track Engineering.

B. Design Speeds

Maximum system speed on the MBTA Rapid Transit and Light Rail lines is 50 mph. Speeds by specific location vary widely due to civil constraints, signal block layout, safety and/or line of sight considerations and other reasons including operating Rule Book limitations. Design speed requirements will be established on a project specific basis by the M.O.W. Division Manager of Track Engineering.

C. Track Geometry

1. General

The parameters for the design of horizontal alignment will be in accordance with the prevailing requirements of the MBTA and with the recommendations of the American Railway Engineering and Maintenance of Way Association (AREMA).

The horizontal alignment of tracks shall consist of tangents connected with circular curves and/or compounded circular curves by spiral transition curves. Vertical alignment shall consist of tangent grades connected by parabolic vertical curves.

2. Horizontal Alignment – Tangent Lengths

a. Mainline Track

Minimum desirable tangent lengths between reverse curves and/or spirals shall be 100 feet. In cases of extreme space limitation and where spiral curves are of sufficient length to provide ½" or less change in reverse cross-level over 62', tangent length may be reduced to the truck center dimension of the most restrictive equipment being operated on the line upon which the design is being done. Short tangents between curves in the same direction should be avoided by compound radius curves or by using mid-spiral geometry.

b. Yard Track

In very rare instances the amount of tangent between reverse curves and/or spirals may be less than the truck center dimension of the most restrictive equipment at the discretion of the M.O.W. Division Manager of Track Engineering. These instances will be limited by the degree of curvature involved and the projected speed of equipment.

c. Special Trackwork

"Back to back" turnouts of the same hand which results in a reverse curve is prohibited unless a tangent length (PS to PS) of at least the truck center dimension of the most restrictive equipment being operated through the turnouts is used. Adherence to this requirement is especially critical in turnouts less than AREMA #10 and absolutely critical in LRT special trackwork design, particularly girder rail special trackwork. LRT TRACK DESIGN REQUIRES THAT AT LEAST 20' OF TANGENT TRACK BE PROVIDED AHEAD OF EVERY TURNOUT. THIS IS A DESIGN REQUIREMENT TO HELP COMPENSATE FOR ROTATIONAL STIFFNESS INHERENT IN CERTAIN LRV TRUCK DESIGNS. THIS PRACTICE WILL ENABLE EACH TRUCK TO BE PROPERLY ALIGNED ENTERING SWITCHES AND MINIMIZE WHEEL FLANGE ANGLE OF ATTACK ISSUES.

3. Horizontal Geometry

a. Curve Definition

Circular curves shall be defined by the arc definition of curvature and specified by the radii.

b. Curve Design

Curvature and superelevation shall be related to design velocity, with consideration of the acceleration and deceleration limits of the equipment to be operated over the track being designed. Whenever possible, curves shall be designed to accommodate the MBTA system speed limit of 50 mph. Limiting factors will include the location and geometry of adjacent curves, station stops, vertical alignment and the performance characteristics of the design vehicle.

c. Station Alignment

At stations on RTL lines, the horizontal track alignment shall be tangent for at least 6 car lengths of the type of equipment being operated plus one car length both entering and leaving the platform. This design practice will enable the lead car entering and the last car of departing trains to be on tangent alignment and will avoid clearance issues. Any deviation from this practice may only be done at the discretion of the M.O.W. Division Manager of Track Engineering.

At LRT station stops, horizontal track curvature will be subject to the limitations imposed by accessible platform design. Additional criteria are available from M.O.W. track engineering staff.

d. Design Considerations

Curve radii, superelevation, length of spirals and design speeds are all interrelated elements. Effective design combines all elements to provide the highest safe and comfortable operating speed possible. The most restrictive curve in a particular section of a RTL or LRT line is the limiting factor. An effective design would investigate means by which the restrictive curve might be modified to more closely match the geometry of other curves in the section.

Other factors potentially impacting speed must also be considered. They are identified in Section **B. Design Speeds**, in this Chapter.

e. Concentric Curve Design

When two or more tracks follow the same general alignment, the tracks shall be concentric in curves. Track centers must be widened to allow for mid and end car overhangs. Refer to Chapter 6, Clearance Criteria, for further information. The preferred method of increasing track centers in curves for clearance reasons is to lengthen the spirals of the inside track to a length where the inside curve spiral offset distance relative to the outside curve spiral offset distance is equal to the required track center increase.

f. Superelevation

Track superelevation is the vertical distance which the outside rail of a curve is raised above the inside rail. Superelevation (also expressed as SE) is used to counteract the effect of centrifugal force on a train as it navigates through curved track. Track SE transition within spirals shall be linear throughout with a suggested rate of run-off of 1” in 80’, a recommended maximum rate of run-off of 1” in 60’ and an absolute maximum rate of run-off of 1” in 40’. The absolute maximum rate shall only be used in extreme cases and only at the discretion of the M.O.W. Division Manager of Track Engineering. In similarly extreme cases dictated by unusual physical constraints, up to 1” of SE may be run off in the tangent beyond end of spiral. This too, may only be done at the discretion of the M.O.W. Division Manager of Track Engineering.

SE shall be constant through circular curves. The top of the inner rail of curves is designated as the “grade rail” and will be maintained at design top of rail profile while the outer rail of curves will be raised above the lower equal to the amount of design elevation. Maximum system design SE is 6” with a maximum design unbalance SE of 3”. Design superelevation shall be calculated using the following formula:

$$Ea + Eu = 4.011 \frac{V^2}{R}$$

Where: Ea = actual superelevation in inches
Eu = unbalanced superelevation in inches

V = design velocity through the curve in inches
R = radius of the circular curve in feet

The ultimate goal of curve design is for Ea + Eu to equal Ee (defined as equilibrium elevation or the amount of superelevation required to exactly counteract the effects of centrifugal force). Design curve velocity shall never exceed that which would be calculated using 6” Ea + 3” Eu. The use of Eu should be limited as much as practically possible due to the effect unbalanced elevation has on outside rail gage face wear, wheel flange wear and passenger comfort.

g. Spiral Transition Curves

Spirals shall be used between tangent track and horizontal circular curves and between horizontal circular curves of different radii where a change in SE greater than ½” is required (mid-spiral). The exception to this practice will be where the ratio of minimum length of spiral required to radius of circular curve in feet is equal or less than 0.01. Spiral curve geometry shall be based on AREMA standards.

h. Gage Widening in Curves

Gage widening is a practice which is a subject of much debate among track design engineers. One theory holds that no gage widening is required and in fact may be detrimental as a contributor to high rail gage face wear. Another theory holds that gage widening is necessary to prevent truck “crabbing” in curves. The current practice on the MBTA RTL and LRT lines is to widen gage in curves less than 1000’ radius. Design gages and maintenance limits for all applications may be found in the M.O.W. Division’s RTL and LRT Track Maintenance Standards.

4. Vertical Alignment

a. General

Profile grade shall represent the elevation of the top of low rail in curves. In tangent track, profile grade shall represent the elevation of top of both rails. (The only exception to this shall be in rare cases where SE is run off in tangent track in which case the top of low rail shall be profile grade).

b. Maximum Gradients

For RTL track between stations, maximum grade shall be 2.9%. Steeper grades up to 4% will only be allowed at the discretion of the M.O.W. Division Manager of Track Engineering. In station areas the maximum grade shall be 0.5%. Yards should be designed level to a maximum grade of 0.25%.

For LRT track between stations, maximum grade shall be also be 2.9% wherever possible. Steeper grades up to 8% will only be allowed at the discretion of the M.O.W. Division Manager of Track Engineering. In station areas the maximum grade shall be 1%. Yards should be designed level to a maximum grade of 0.25%

c. Vertical Curves

All vertical curves shall be parabolic and have a constant rate of change of grade. For both RTL and LRT track, the length of curve will vary according to speed, but in no case shall be less than 100' except at the discretion of the M.O.W. Division Manager of Track Engineering. The maximum rate of change of grade for sag and crest vertical curves in RTL track shall be 0.015%. The minimum vertical curve radius (crest) in LRT track shall be 300'. The minimum vertical curve radius (sag) in LRT track shall be 400'.

d. Minimum Tangent Lengths

The preferred minimum tangent length between vertical curves for both RTL and LRT track shall be 100'. The absolute minimum tangent length between vertical curves shall be 50'.

e. Combined Horizontal and Vertical Curvature

In LRT track, the worst condition combined horizontal and vertical curves shall be 50' centerline radius horizontal and either 400' radius sag vertical curve or 300' radius crest vertical curve. This type of geometry will be allowed only at the discretion of the M.O.W. Division Manager of Track Engineering.

SECTION 4

TRACKWORK DESIGN CRITERIA

A. General

All materials, assembly and construction practices shall be in accordance with generally accepted transit industry standards and shall conform to current AREMA standards where applicable. Further, all material procurement will be governed by the appropriate MBTA MATERIAL SPECIFICATION where such a specification exists, and in the absence of an MBTA MATERIAL SPECIFICATION, by the current AREMA criteria which applies to the material being procured. Trackwork assembly and track construction will be in accordance with this Design Standards Manual, the MBTA Book of Standard Trackwork Plans and/or any applicable AREMA standards.

B. Track Construction Methods

Track construction choice for any new installation or renewal will be at the direction of the Director M.O.W. and/or the M.O.W. Division Manager of Track Engineering. Decisions will be based on previous experience of the MBTA and of other transit properties with respect to economics, performance and maintenance considerations.

Standard track construction shall be with resilient fasteners on either timber or concrete ties in ballast as directed by the above named persons. Standard ballasted construction will be used throughout except on bridge structures, viaducts or in tunnels where directly fixated track construction may be used as directed.

Prior to the identification of a choice of track construction for any new installation or renewal, an analysis shall be performed to determine the cost of procuring, constructing and particularly, maintaining the track, during the course of its projected life cycle. All projections and assumptions to be used for the analysis shall be submitted to the M.O.W. Division Manager of Track Engineering for review and approval.

C. Track Materials

All track design will incorporate standard track materials currently in use on the MBTA. Any exceptions will be only at the discretion of the M.O.W. Division Manager of Track Engineering. All materials shall meet MBTA requirements as indicated in Section A of this Part with respect to material procurement.

1. Running Rail

The standard rail section for new all RTL and LRT track construction is 115 RE continuous welded rail. Rail shall meet MBTA Specifications as described in the Book of Standard Track Material Specifications. The use of a girder or grooved rail section in certain LRT applications may be required as directed by the M.O.W. Division Manager of Track Engineering. Standard control cooled rail shall be used for all construction/renewals except:

a) On the high side of all mainline curves less than 1500' radius,
b) On both sides of all double restrained curves,
c) Within all turnouts and other special trackwork,
d) On the high side of all mainline curves less than 2500' radius where the Eu value is in excess of 1" and,
e) In locations where frequent braking or acceleration would regularly occur such as entering, departing or within station areas, on steep grades, approaching timing signals or otherwise at the direction of the M.O.W. Division Manager of Track Engineering.

Head-hardened rail shall be used in lieu of control cooled rail in a) through e) as described above. Head-hardened rail shall be used through spirals of curves qualifying for use its use as indicated and also through tangents between adjacent qualifying curves wherever the tangent is less than 200'. Both control cooled and head-hardened rail shall be weldable by either flash-butt or thermite processes.

2. Restraining Rail

Standard restraining rail to be used shall be head-hardened 132 RE modified as shown on Standard Plan No. 305. Restraining rail will be installed adjacent to the low rail in all curves in both RTL and LRT track less than 1000' radius. Restraining rail will be installed on both the low and high side of all curves less than 100'radius. In special circumstances, restraining rail may be used in curves greater than 1000' radius and double restraining rail in curves greater than 100' radius at the direction of the M.O.W. Division Manager of Track Engineering.

3. Wooden Cross Ties and Switch Timbers

Ties and switch timbers shall meet the MBTA Specifications as shown on Plan No. 200 in the Book of Standard Trackwork Plans and as described in the Book of Standard Track Material Specifications.

Typical crosstie spacing in both RTL and LRT track is 20" on center except in transition areas as shown on Standard Plan No. 215 and for grade crossing applications as shown on Standard Plan Nos. 145, 150 and 155.

Typical crosstie length is 8'-6" in LRT track (except at grade crossings – see Standard Plan Nos. 145, 150 and 155) and in RTL track without third rail. Typical crosstie length in RTL third rail territory is 9'-0" as shown on Standard Plan No. 860.

Switch timber length and spacing shall be as indicated on the special trackwork drawings as shown in the Book of Standard Trackwork Plans.

4. Concrete Ties

Concrete ties shall meet the MBTA Specifications as shown on Plan No. 205 in the Book of Standard Plans and as described in the Book of Standard Track Material Specifications.

Typical concrete tie spacing throughout the MBTA system shall be 30" on center.

5. Subballast

New track construction shall call for the use of subballast material whenever the existing subsurface conditions are unsuitable. Suitable conditions mean free draining, granular, dense graded material which contains little to no organic matter. Typical subballast sections are shown on Standard Plan Nos. 100, 105, 125, 130, 135 and 140. The use of engineering fabric, HMA underlayment or other means to ameliorate undesirable soil conditions is necessary when an unstable, poorly drained subsurface situation is encountered. In locations where a history exists of difficulty in maintaining track surface or test pits/borings indicate unsuitable subsurface conditions, measures shall be taken that will provide adequate support for the track structure.

6. Ballast

Crushed stone ballast meeting the requirements set forth in the M.O.W. Division Book of Standard Track Material and Construction Specifications shall be used in MBTA RTL and LRT track. Ballast size shall be AREMA No. 4 unless otherwise directed by the M.O.W. Division Manager of Track Engineering. Standard ballast depth is to be 12" below bottom of tie under the low rail. Any proposed exceptions to the standard ballast depth must be approved by the M.O.W. Division Manager of Track Engineering. Optimum ballast section design is indicated on Standard Plan Nos. 100, 105, 125, 130, 135 and 140.

During track reconstruction, rail replacement and/or tie renewal projects, care must be taken to maintain an adequate ballast section to protect the lateral stability of the track structure. This is particularly true in CWR territory and when rail temperature is above the neutral zone (90^0 – 110^0 F).

7. Tie Plates

The MBTA standard for use in RTL and LRT track on timber crossties is resilient fastener tie plates with lockspikes as shown in the Book of Standard Trackwork Plans. In special circumstances or as directed by the M.O.W. Division Manager of Track Engineering, screw spikes may be specified. Such circumstances might include sharp curves where lateral rail movement under load may occur.

8. Spiking Patterns

Refer to Standard Plan No. 210 for details of spiking requirements.

9. Resilient Fasteners

Resilient fasteners with matching tie plates on timber crossties is the MBTA standard for new and reconstructed track. Refer to the detailed specification for resilient fasteners in the Book of Standard Track Material and Construction Specifications. In the interest of standardization and based upon the positive experience of the MBTA since 1980, resilient fasteners manufactured by Pandrol should be used wherever possible. Pandrol cast-in shoulders, resilient fasteners and tie pads should be specified for use with concrete ties. For other applications such as in direct fixation track or on open deck bridges, impact attenuating composite tie plates that accept the standard resilient fastener should be evaluated for use.

10. Special Trackwork

The MBTA standard for special trackwork construction is AREMA-based design using 115 RE rail section on wooden switch timbers. (Cast manganese girder rail or machined monobloc special trackwork design for LRT track may be required at the direction of the M.O.W. Division Manager of Track Engineering.) Since an AAR wheel profile is used on the equipment that operates on the RTL lines, special trackwork design for the RTL lines follows AREMA guidelines very closely. One important difference is the use of guarded switches. All switches on the MBTA less than AREMA No. 10 must be fully guarded, using restraining rail, a double switch point and a cover guard. This requirement is driven by the MBTA standard practice of applying restraining rail to the inside rail of all curves less than 1000’ radius.

LRT special trackwork design differs significantly from RTL special trackwork because the wheels on LRT equipment are not AAR design. The wheel profile on LRT equipment was developed by the American Transit Engineering Association (the A.T.E.A.) and is much narrower than AAR designs, has a thinner, shallower flange and totally different flange geometry. As a result, LRT special trackwork design uses different switch point and stock rail details and flange bearing frogs. Refer to the

Book of Standard Trackwork Plans and the Book of Standard Track Material and Construction Specifications for details of components used in turnouts, crossovers and rail crossings for both RTL and LRT trackwork design.

For RTL track and to a lesser degree LRT track, the longest turnout possible for a given location should be used in mainline track. Longer turnouts equal greater operating speed through the curved side of the turnout translating into shorter trip times. The longest turnout used on the MBTA system is AREMA-based design No. 20. The shortest turnout used on the Blue Line is a compounded 75’ radius fully guarded, on the Orange Line a fully guarded 150’ radius, on the Red Line a fully guarded 150’ radius and on the Green Line a fully guarded 50’ radius.

Shorter turnouts are used to maximize train storage and because the MBTA is a 100+ year old system which was originally designed when special trackwork fabrication and labor (in the form of track maintenance forces) was much cheaper than they are today. Trackwork designers need to be aware of the additional costs associated with fabricating non-standard special trackwork and maintaining shorter radius turnouts which, because of their geometry, are subject to greater wear.

11. Switch Stands

12. Bumping Posts

Details of bumping posts to be used on RTL and LRT track are given at Plan Nos. 920 and 925 in the Book of Standard Trackwork Plans.

13. Emergency Guard Rails

a. Bridges

Emergency guard rails (double rail) shall be used on all bridges throughout the MBTA system regardless of the type of bridge construction or span length. Details of emergency guard rail design are shown on Plan Nos. 900 and 905 in the Book of Standard Trackwork Plans. Details of emergency guard rail fastening are particularly important as they relate to the facilitation of track surfacing and other maintenance operations.

b. Downgrades

Emergency guard rail (double rail) shall be used on all downgrades of greater than 3% in mainline track throughout the system.

c. Other Locations

Single guard rail use and/or crash walls may be required at locations where a derailed train would cause significant structural damage to adjacent vulnerable facilities or to the train itself. Some examples of such installations include:

- Where tracks pass steep drop-offs to water or where a derailed train would potentially fall a considerable distance.

- Where tracks pass in close proximity to high voltage structures such as power substations.

- Where tracks pass critical bridge supports, etc. and the impact of a derailed train would potentially cause sudden catastrophic failure of the bridge or structure. This circumstance could dictate the requirement of a crash wall. Such a requirement shall be at the discretion of the M.O.W. Division Manager of Track Engineering.

14. Crash Walls

When tracks are immediately adjacent to supports for bridges, buildings and air rights development above the tracks, such supports should be protected from the potential impact of derailed train. This protection shall be in the form of emergency guard rail and, at the direction of the M.O.W. Manager of Track Engineering, crash wall(s).

The impact design loading for crash walls shall be as follows:

- Train weight for the largest loaded consist which may operate over the track at the location under consideration. Further information is available from the M.O.W. engineering staff.

- The "angle of attack" of the impact load shall be ten degrees.

- The impact speed shall be authorized speed for operating equipment at the location plus 50%.

- Piers and abutments shall be located so that a square hit by a derailed train is not possible. Structures should be designed to deflect a train away from potential square hits.

Refer to the current AREMA Manual for additional information on crash wall design.

15. Contact Rail

Contact rail (a.k.a. third rail) is used on the Red Line, on the Orange Line and on the Blue Line between Bowdoin and Airport Stations. The MBTA standard contact rail for new track construction is 85# composite rail. Refer to details of the rail, splice bars, end approaches, insulators, insulator screw lags and third rail anchor assemblies on Plan Nos. 860, 865 and 870 in the Book of Standard Trackwork Plans.

SECTION 5

ROADWAY DESIGN CRITERIA

A. SUBGRADE

1. General

Track structure cross-section shall comply with the dimensional requirements given on Plan Nos. 100, 105, 125, 130, 135 and 140 in the Book of Standard Trackwork Plans. The minimum subgrade cross slope should be ¼" per foot to drain water from the track structure. Final subgrade elevation in either cuts or fills shall be set to allow placement of design trackbed section at design profile grade. The standard roadway section shown on Plan Nos. 100, 105, 125, 130, 135 and 140 will be used only when existing subgrade conditions are satisfactory. The design of trackbed sections in poor subgrades will require the inclusion of additional measures to provide a stable and maintainable track structure.

When track reconstruction is planned at a location, the following steps must be taken to determine if a requirement exists for additional measures to be considered for roadway design:

a. Inspection of existing track structure for obvious signs of subgrade failure (muddy or fouled ballast conditions, poor track surface and/or horizontal alignment, standing water in track structure, slope erosion, evidence of washouts and the presence of vegetation in the trackbed.

b. Interviews with appropriate maintenance personnel (i.e., Supervisor, Section Foreman) for historical perspective on any known problem areas which have been difficult to maintain.

c. Execution and observation of test pits at any locations which are suspected as unstable with poor subgrade conditions.

d. Possible use of test borings to ascertain subgrade conditions at major problem areas. For new track construction where no track has existed previously, the use of test pits and/or borings should be included as part of the standard design process to determine subsurface soil conditions.

The use of HMA (hot-mix asphalt) underlayments shall be considered for installation beneath turnouts, vehicular grade crossings or at other locations with poor subsoil conditions where the additional expense can be justified. HMA underlayments will be required at discretion of the M.O.W. Division Manager of Track Engineering.

2. Fill Sections

In new track construction, fill foundations must be explored, analyzed and then designed to prevent failure of the subsoil or excessive settlement. Exploration/analysis should be conducted as indicated in the AREMA Manual. The use of sand or wick drains and surcharging may be necessary to consolidate compressive soils prior to track construction.

When widening existing fills, benching the existing slope and placing new fill in compacted lifts not over two feet in depth must be detailed in the construction plans and specifications. Dumping material down the slope is unacceptable except for fills less than 5’ deep or when placing rip-rap for erosion control. Existing culverts shall be investigated, protected or extended as required.

3. Cut Sections

Cut sections pose particular problems with respect to drainage and soil stability. Within existing cuts it is imperative that side ditches are maintained – cleaned, restored to their original capacity and lowered to a sufficient depth (at least 4’-6” below top of rail. Ditches should also be graded to drain. Where ditches of required depth and cross-section are not possible, underdrains and closed drainage systems must be provided.

Visual inspection of all cut slopes for signs of instability and/or the presence of excessive moisture is necessary. If widening of cut slopes is indicated, investigate slope stability and recommend construction methods and materials that will ensure the finished slope can be maintained in a stable condition. Top of cuts should be inspected for ponding and mitigation measures detailed.

The track bed within existing cuts often is composed of non-granular material which fouls ballast quickly and is resistant to proper drainage. Such conditions should be remedied to the greatest extent possible during track reconstruction. Excavation of unsuitable materials, installation of additional underdrains, use of engineering fabric or HMA underlayments should be considered to improve roadbed stability and lower the cost of maintenance.

B. DRAINAGE

1. General

Proper drainage design and maintenance are critical to the integrity of the track structure. Some drainage related problems not only threaten track structure integrity, they can be serious safety issues as well. As a result, whether building new track or reconstructing existing track, it is essential that track structure drainage is given very close consideration.

When engineering new or reconstructed roadbed for removal of surface and groundwater, the following general conditions shall apply:

- Existing, natural drainage patterns shall be maintained wherever possible.

- To the greatest practical extent possible, surface and subsurface drainage of the roadbed should occur within a system of free flowing gravity-based longitudinal ditches that feed into established man-made drainage structures or natural waterways.

- Mid-ditch low points should obviously be avoided. However, in circumstances where low points cannot be avoided, positive means of water removal from the ditch must be provided. Such means may include tying into municipal systems, the use of leaching basins or detention ponds, transverse ditches, culverts,etc.

- In cases where a gravity-based system is impossible to design, the use of pumps may be considered to ensure positive drainage of the trackbed. The design flow of a system that includes pumps shall include an allowance for groundwater infiltration.

- Drainage systems that discharge to a wetland or are within 100’ of a wetland must comply with the requirements of the Wetland Protection Act and any additional local regulations. The local conservation commission must be contacted, informed of project scope and advised of any impact on existing wetlands.

- Drainage systems designed to connect to an existing system which discharges to a wetland must meet the same criteria as outlined above. In addition, approval is required from the owner of the drainage system into which any additional outflow is proposed to go.

2. Mainline Trackbed Drainage Criteria

a. Each track in a right-of-way should drain individually to its own ditch or subdrain. Adjacent tracks should not drain toward or across one another.

b. Area within the right-of-way beyond the trackbed should not drain through the track structure. Typically, a ditch or subdrain should be located between the track and adjacent area to be drained to intercept material which might act to foul the ballast of the trackbed.

c. Typical drainage for double track roadbed section is from a crown on the centerline between the two tracks to a ditch or subdrain on the field side of the tracks. Where a double track section is located between walls or other obstructions to the field side, a subdrain may be located between the tracks to drain both tracks.

d. Typical drainage for single track roadbed is from a crown on the centerline of track to ditches on either side of the track. When a single track is located between walls or other obstructions, the ditch or subdrain may be on one side of the track and the subgrade sloped accordingly.

e. At side platform stations, the platform should always drain away from the track. Trackbed drainage should be handled by a subdrain located between the track and platform. At LRT platforms with raised curbing or Jersey barriers at the back edge of platform, scuppers should be designed to drain water from the back of platform or other methods employed to drain water away from the track area.

f. At center platform stations, the platform should be crowned in the center to distribute drainage equally between the two tracks. Trackbed drainage shall then be designed to carry water out of the track area.

3. Design Considerations

a. Design Storm Computation

1. Rational Equation

Design flows for local drainage shall be calculated by the Rational Equation --- Q = CIA

where : Q = Runoff quantity, in cfs
C = Coefficient of runoff

I = Rainfall intensity, in inches per hour
A = Drainage area, in acres

2. Design Frequency

The track drainage system including all areas within a right-of-way exposed to direct precipitation shall be designed to accommodate the peak flow produced by a 50 year rainfall event. All runoff from the exposed area shall be fully contained within the drainage system and the capacity of all drainage conduits shall equal the 50 year runoff.

The drainage system for non-mainline track areas shall be designed to accommodate flow from a 10 year storm. Where the drainage system is tied into a municipal storm drain system, the capacity of the receiving system shall be investigate to determine if there is adequate capacity to handle the additional drainage.

3. Time of Concentration

The minimum time of concentration used shall be 5 minutes.

Time of concentration shall be determined by the equation:

$$Tc = (0.0078\ K\ L^{0.77})/S^{0.385}$$

where:

Tc = Time of concentration, in minutes
L = Maximum length of travel from most remote spot in drainage area to outlet, in feet
S = Average slope (feet/foot) = H/L
H = Difference in elevation between most remote point (as in L) and drainage outlet
K = 1.0 for natural basins with well defined channels, for overland flow on bare earth and for mowed grass roadway channels
K = 2.0 for overland flow over grass surfaces
K = 0.4 for overland flow, concrete or asphalt surfaces
K = 0.2 for concrete channel

For areas with abrupt topographic changes, the above calculation shall be done for each topographical segment and the total time of concentration arrived at by adding the calculated times for each segment added together.

4. Rainfall Intensity

Rainfall intensity shall be obtained for specific design storm frequencies and times of concentration by using the Rainfall Intensity-Duration-Frequency Curve for Boston, MA, as found in Technical Paper No. 25 of the U.S. Dept. of Commerce, Weather Bureau, December, 1966.

5. Coefficient of Runoff

Values of runoff coefficient for use in the Rational Equation (Q=CIA) shall be as defined in ASCE Manual No. 37, Design and Construction of Sanitary and Storm Sewers or Table 1 on Page 53 of Design of Roadside Drainage Channels, Hydraulic Design Series No. 4, U.S. Department of Commerce, Bureau of Public Roads, May, 1965.

b. Ditches

1. Geometric Requirements

Ditches shall be trapezoidal with a minimum depth of 18 inches and a minimum bottom width of 2 feet. They shall have a minimum gradient of 0.25% and a maximum design velocity of 2 feet/second for unlined channels. Water levels in ditches at design flow rates shall be at least 3 feet below the top of rail.

2. Flow Computation

Drainage velocities and capacities shall be calculated through the use of Manning's Equation --- $V = 1.486/n \times R^{2/3}S^{1/2}$

where:

V = Velocity, in ft/sec
n = Manning's Coefficient of Roughness
R = Hydraulic Radius, in feet
S = Slope, in feet/foot

Manning's "n" values shall be determined from ASCE Manual No. 37 or Table 2, Page 53-54 of Design of Roadside Drainage Channels, Hydraulic Design Series No. 4, U.S. Dept. of Commerce, Bureau of Public Roads, May 1965.

3. Gutter Flows and Inlets

Where curbing is proposed along roadways, gutter flows and gutter inlets shall be designed in accordance with the U.S. DOT – Federal Highway Administration Hydraulic Engineering Circular No. 12, Drainage of Highway Pavements, March, 1984. At least 10' of the travel way shall be free of gutter flows.

c. Storm Drains

1. Material Requirements

Reinforced concrete or asphalt-coated corrugated metal pipes shall be used for drainage. Minimum diameter pipe size shall be 12 inches. Culverts shall have a minimum diameter of 18 inches.

Pipes under tracks shall be designed for Cooper E80 loading and shall have a minimum cover of 2 feet from bottom of tie to top of pipe.

Pipes under roadways, parking lots or driveways shall be designed for H20 loading. They shall have a minimum cover of 1 foot from top of pavement to top of pipe.

2. Flow

Manning's Equation, as defined in the Ditch Section and as shown below shall be used.

$$Q = 0.463D^{8/3}/n \times S^{1/2}$$

where:

full capacity

S = Pipe slope in feet/foot
Q = Flow (cubic feet per second)
n = Manning's roughness coefficient
D = Pipe diameter (feet)

Pipes shall be designed for uniform flow, with a preferred velocity in the range of 3 to 9 feet per second. Maximum headwater for culverts shall be 1-1/2 times the pipe diameter. At design flows, water shall not back up at the pipe entrance to an elevation higher than six inches below top of track subgrade or roadway pavement.

Pipes shall not be designed to be a smaller diameter than the next pipe upstream

3. Track Drains

Track drains shall be constructed as shown on Plan No. 910 in the Book of Standard Trackwork Plans and as described in the Book of Standard Track Material and Construction Specifications.

4. Manholes

Manholes shall be installed at all pipe junctions, changes in grade and changes in horizontal alignment. Maximum pipe length between manholes shall be 300 feet.

5. Catch Basins

Catch basins shall be installed at all ground or pavement surface low points and on all grades not drained by ditches or other means. The maximum interval between catch basins shall be 300 feet.

Catch basins shall have a 30 inch deep sump, a cast iron hood, frame and bicycle safe grate. General design of catch basins must allow for unobstructed clean-out with a clam shell bucket.

d. Perforated Pipe Drains

In locations where ditches are impractical due to space limitations, where additional flow is required to meet capacity or where necessary to reduce subsurface hydrostatic pressure, perforated pipe drains shall be used. Material shall be perforated bituminous-coated galvanized corrugated metal or perforated PVC. Minimum size shall be eight inch diameter in grade crossing applications and 12 inch diameter when used in place of ditches.

When used as underdrains to reduce hydrostatic pressure and control groundwater elevation, the pipe perforations shall face down. When used as water-carrying conduits with groundwater control as a secondary element, the pipe perforations shall face up. The use of perforated pipe as water-carrying conduit is limited to the upper runs of a drainage system and shall be checked to ensure that they will not be subject to surcharging. Carrier pipes for storm drainage distinct from perforated pipes shall be used in combination with perforated pipes in most cases.

Filters around the outside perimeter of perforated pipes shall be used to prevent the accumulation of sediment in the pipes. The filter material shall be suitably graded, crushed stone, synthetic filter material or a combination of both. The filter envelope shall extend a minimum of eight inches beyond the outside diameter of the pipe.

Perforated pipe drains shall discharge to a gravity drainage system, pump station or in special circumstances, to daylight on the downhill side of grade crossings. Pipe drains shall not be blocked by high water levels at their outlets. Impervious materials shall not by installed on top of pipe drains.

MHWA design gas traps or oil-water separators shall be provided in areas where runoff is subject to contamination with petroleum products and where required by local regulations.

e. Detention Ponds

Detention pond design shall be necessary to limit peak outflow from the design storm to an acceptable value. When the discharge from a detention pond is into a wetland, a review by the local conservation commission is required. The detention pond shall include provisions for sediment removal, if warranted. Each pond being designed shall be evaluated to determine if a sedimentation basin is justified by the amount of sediment potentially to enter the pond.

Detention pond design shall include an emergency overflow section to allow for the safe discharge of water in excess of the design storm. Multiple outlets may be used when needed to accommodate maximum and minimum design storms. Required storage volume shall be determined using inflow and outflow hydrographs based on the Soil Conservation Service criteria or another approved method.

f. Recharge Basins

Recharge basins shall be designed with both a sedimentation basin section and a recharge basin section. The sedimentation basin shall be designed to remove all sediment that might plug the pores and reduce the basin's infiltration capacity.

The recharge basin section shall be designed to allow infiltration of the design storm within a reasonable period of time. The recharge basin capacity may be supplemented by recharge wells or trenches. The infiltration capacity shall be based on percolation field tests. Deep hole field tests shall be used to determine the depth to ground water and/or the location of impervious strata.

The total storage capacity of the recharge and sedimentation basins shall be adequate to contain the runoff from the design storm.

g. Erosion Control

1. Grading

Cut and fill slopes shall be designed to be as flat as possible without creating any ponding situations. Minimum slopes to provide positive drainage will suffice. Mowed areas shall have a 1% minimum slope and unmowed areas a 2% minimum slope. Mowed areas shall not exceed 3:1 horizontal to vertical and unmowed areas shall not exceed 2:1. Any slope steeper than 2:1 will require goetextile, rock or other treatment to control erosion. The tops and toes of all slopes shall be rounded.

2. Diversion Channels

Diversion channels shall be designed at the top of all steep cut slopes where the terrain continues to rise away from the track area. Channels shall be designed in accordance with the requirements of this part and will discharge to the storm drainage system or a natural water course. Channel outlets shall be designed to minimize erosion. Discharges into existing wetlands or within 100’ of wetlands shall be in compliance with the rules and regulations of the local conservation commission.

3. Grade Stabilization Structures

Where storm water needs to be conveyed from one level to another across a steep slope, a grade stabilization structure shall be used. The structure may be a culvert, lined chute or other acceptable means.

4. Vegetation

Construction grading operations shall minimize disturbance to vegetation within the construction area. Phased construction shall be used where practical to minimize the exposure of bare earth and erosion that inevitably ensues. Erosion control matting shall be used as directed to minimize erosion until disturbed earth can be revegetated. Vegetation requirements shall be coordinated by a landscape architect with the MBTA and the appropriate municipality.

5. Municipal Requirements

Construction work within a wetland area or adjacent to a wetland area requires notification of the local conservation commission. A Notice of Intent shall be filed, if necessary, and any requirements of the conservation commission shall be incorporated into the design. Sedimentation and erosion control are typically required by conservation commissions. Silt fences, straw bale checks, staged construction and revegetation requirements shall be incorporated into the design as needed.

C. FENCING

1. General

Fencing shall be required on all MBTA rights-of-way at the direction of the M.O.W. Division Manager of Track Engineering. Fencing is absolutely required in all third rail territory for the protection of the general public, domestic and wild animals and the MBTA's passengers. Fencing in yards, maintenance facilities and on non-third rail RTL and/or LRT track in urban areas will be required on a project specific basis.

2. Fencing Types

The typical R.O.W. fence is 72" chain link. Higher fencing and the use of three-strand barbed wire may be required. High Security Fence consisting of very dense, closely spaced mesh fabric with closer than normal post spacing may also be required in limited areas where vandalism is a problem.

At overhead bridges, special fence mounting details are required including posts and fabric which curve back into the bridge to prevent the throwing or dropping of objects onto the track area. Such fencing is known as anti-missile fencing.

Gates in R.O.W. or yard fencing may be required as directed. Gates may be single swing, double swing or sliding as necessary to suit the required use. In any case the design of the gate and all related hardware must be the heaviest duty and most durable to provide reliable service over the life of the installation.

Treated timber fencing of permanent construction may be used to control snow drifting or as an alternative to chain link right-of-way fencing as directed.

3. Fencing Uses

a. Right-of-Way Fence

Fencing along the RTL or LRT rights-of-way prevents unauthorized entry and also defines MBTA property and that of the MBTA's abutters. As described in 2. Fencing Types, right-of-way fencing is used along both sides of a right-of-way and is typically 72" chain link.

Gates must be located at appropriate locations to allow maintenance and operating personnel access to the right-of-way. Access is particularly important at interlockings, bridge approaches, unit substations and other facilities at which regular visits by personnel are made.

At problem locations or where specific circumstances dictate its use, segments of higher (96") or High Security Fencing may be required.

b. Intertrack Fencing

Ornamental aluminum fencing is sometimes used between LRT tracks in urban areas where train traffic is restricted to 25 mph or less, regularly crosses city streets and where right-of-way fencing is impractical. Intertrack fencing is typically 60" or 72" high, is painted dark grey or black and resembles wrought iron fence, runs continuously between vehicular crossdrives or stations and is intended to be a deterrent to persons crossing the tracks.

c. Overhead Bridges

Both pedestrian and vehicular bridges are susceptible to vandalism in the form of projectiles being thrown onto trains and/or rights-of-way. Anti-missile fencing should be used on bridges that cross MBTA tracks. Anti-missile fencing consists of curved posts and fabric that make throwing of debris onto tracks difficult. Fan guards and cantilever fence sections may be used where anti-missile fencing ends on bridge approaches.

d. Fencing Setbacks

Typical right-of-way fencing shall be installed one foot inside of actual right-of-way property lines on MBTA property. Where special circumstances exist, this dimension may vary at the direction of M.O.W. engineering staff.

D. RIGHT-OF-WAY SIGNS AND MARKERS

1. General

Many different types of signs are required for use on RTL and LRT tracks. Some are for informational purposes for the general public, some are for use by MBTA personnel. During new construction or major reconstruction of existing facilities, furnishing new or replacing existing signs will be part of the project scope.

Examples of signs that are required include:

- Speed signs
- Engineering stationing markers
- No trespassing signs
- Third rail warning signs
- Cable/ductbank warning signs
- Bridge identification signs
- Headway signs
- Miscellaneous (pump room, emergency exit, etc.)

All signs shall conform to the requirements given in the Book of Standard Track Material and Construction Specifications and are to be provided at the direction of the M.O.W. Division Manager of Track Engineering.

SECTION 6

GRADE CROSSING CRITERIA

A. General

Vehicular grade crossings and pedestrian crosswalks are present on the MBTA system on Huntington Avenue, Beacon Street, Commonwealth Avenue and the Mattapan Line. In addition, crossings for agricultural equipment and pedestrians are found on the Riverside Line. Mounting "pads" for M.O.W. work equipment are on every line.

Crossings of all types are potentially hazardous to train and motor vehicle operation and to pedestrian traffic as well. Proper crossing design will consider all elements of the crossing's usage. Important considerations include the volume of vehicular traffic, road profile, crossing and track structure drainage, track geometry, pedestrian traffic flow and the presence of subsurface utility structures, among others.

Crossing maintenance is also an important consideration. The track structure beneath a crossing surface is subject to accelerated deterioration due to infiltration of road sand and salt, heavy truck traffic and wet, corrosive conditions. This is particularly true of asphalt crossings that generally have a life expectancy of 10 years in mainline track and should be programmed for replacement accordingly. Crossings need to be built to a very high standard of construction with proven materials that will withstand the abuse to which they are subjected and which may be readily removed/replaced should track maintenance be necessary.

B. Types of Crossings

Most vehicular grade crossings on Huntington Avenue, Beacon Street and Commonwealth Avenue are busy cross streets that justify the added expense of full-depth rubber crossing material. Specifications for full-depth rubber crossings are found in Paragraph F, Part 2 of this Section. Cross-sections and details of grade crossing construction are found in the Book of Standard Trackwork Plans.

Vehicular crossings that do not have a high volume of traffic are potential candidates for the use of rubber rail seal or plain bituminous asphalt construction. Specifications for rubber rail seal are found in Paragraph G, Part 2 of this Section. Cross-sections and details of grade crossing construction are found in the Book of Standard Trackwork Plans.

Crossings with curved track less than 1000' radius within them must include restraining rail. These crossings shall be bituminous type construction with rail seal used on one rail in the case of single restrained curves. Crossings with significant superelevation or with substantial grade separation between tracks may use full-depth rubber panels between the rails of each track and rubber rail seal on the field side of each rail. This may need to be done to ease the vertical transition between tracks for crossing vehicles.

Pedestrian crossings may be rubber, asphalt, a combination of rubber and asphalt or wood. Determinations for the type of crossing surface to be used in all cases will be made by the M.O.W. Division Manager of Track Engineering and/or the Director – M.O.W.

C. Design Criteria

1. Subgrade

In the process of crossing reconstruction design, the nature and composition of the subgrade shall be determined. The presence of a well-compacted granular subgrade with favorable drainage characteristics is important.

Should poor subgrade conditions be in evidence by observation of fouled ballast, standing water, mud or other indications, subsurface investigation must be conducted to determine the extent of the problem. Depth of excavation for the track construction will be dependent on the results of the subsurface investigation. Generally, subgrade remediation will be required when the subgrade resilient modulus (Es) is less than 7500 psi or when the California Bearing Ratio is less than 5.0.

Typical track structure cross-section for grade crossing construction is shown on Plan Nos. 150 and 155 in the Book of Standard Trackwork Plans. Additional measures of subgrade stabilization including, but not necessarily limited to, the use of engineering fabrics or a bituminous concrete underlayment should be considered in the event of substandard subgrade conditions. Any subgrade treatment should only be placed on granular material that will allow lateral movement of water to a properly designed drainage system.

2. Track Structure

As stated previously, typical cross-section for grade crossing reconstruction is shown on Plan Nos. 150 and 155 in the Book of Standard Trackwork Plans. Track structure shall consist of 12” of AREMA No. 4 stone ballast on top of a compacted subgrade (meeting criteria herein) or on top of an acceptable subgrade treatment; 7” x 9” x 9’-0” crossties on top of the compacted 12” ballast layer at spacing required by the rubber crossing panel manufacturer or at 18” in the case of rubber rail seal or bituminous asphalt crossings; 115 RE CWR on resilient fastener plates with resilient fasteners to the limits of crossing reconstruction or 50’ beyond the edge of crossing, whichever is further. No rail joints to be permitted within the crossing or within 50' either side of the crossing surface unless specifically directed otherwise.

Rail strings in crossing reconstruction are to be destressed by artificial heating, if required, to achieve neutral rail temperature before field welding to existing rail. Details for installing welded rail may be found in Specification 02867 – CWR Installation in the Book of Standard Track Material and Construction Specifications.

Ballast in tie cribs and off the ends of ties to the limits of asphalt saw-cutting is to be mechanically compacted after the completion of tamping. Tamping, to be undertaken after track is adjusted to final line and grade, shall consist of a minimum of two passes with a minimum of two insertions per pass with rail mounted vibratory tamping equipment satisfactory to the MBTA.

3. Conduits

The placement of conduits during crossing reconstruction may be required. These conduits may be for MBTA signal and/or communication use, city or town traffic signal use or for other utility uses. Conduits would generally be 4” Galvanized Rigid Steel (GRS) although other sizes and materials may be required. Conduit installation will be site-specific and details are to found on the individual crossing drawings.

D. Drainage Criteria

1. General

Removal of surface water and reduction of pore water pressure in the subgrade beneath crossings are critical to the ability to maintain a trouble-free crossing. Means of water removal will typically be by track drains connected to catch basins or other drainage structures and/or perforated pipe underdrains to either existing municipal drainage systems or to French drains.

2. Underdrains

Perforated pipe underdrains set in stone filled trenches on either side of the track structure (reference Plan No.   in the Book of Standard Trackwork Plans) protected from clogging by filter fabric are an effective means of removing water from the crossing area and lowering pore water pressure. The success of the underdrains is dependent an outlet from them to a lower point. If an outlet to the municipal drainage system is available, it may be used. Permission from the municipal authority is required. Otherwise, drains may be directed to daylight at some point downhill from the crossing.

E. Existing Utilities

Due to the fact that most grade crossing reconstruction work will take place in a heavily urban area at predominantly major intersecting streets, the presence of utilities is almost guaranteed. These utilities may be in the form of high voltage electrical duct banks, telephone or other communication ducts, gas lines, water lines, sewer lines, traffic signal conduits and others. Although most utility lines should be beneath the level to which excavation would typically take place during crossing reconstruction, assumptions as to the depth or location of utilities must never be made. The presence and condition of all utilities in the crossing area must be determined prior to the beginning of construction. Protection and any proposed replacement of utilities should be coordinated with the responsible utility in advance to minimize the possibility of damage or disruption to the utility facilities.

F. Full-Depth Rubber Crossing

Part 1 – General

1.01 Quality Assurance

a. All work associated with grade crossing design, construction and material procurement for grade crossing construction will be in conformance with all applicable sections in the MBTA Book of Standard Trackwork Plans, the Book of Standard Track Material and Construction Specifications and the Transit Design Standards Manual.

b. All codes and regulations of the municipal authorities within whose jurisdiction the installation of the rubber crossing will take place shall apply. In addition, the standards and specifications of any utilities whose facilities may be impacted by crossing work shall also apply.

1.02 Submittals

a. Shop Drawings – Submit for approval, within 30 days of receiving the Notice to Proceed from the MBTA, details of the crossing system proposed to be installed. Included must be the rubber crossing manufacturer's literature in which drawings and detailed installation instructions may be found.

b. Working Drawings – Submit detailed information about any proposed modification to the standard rubber crossing configuration indicated on MBTA Plan No. . Such modifications would include, but would not be limited to, different tie spacing.

c. Submit for approval, if required by the Engineer, a tie layout plan showing the tie spacing, tie length and track gauge for each tie. Tie layout plan must take into consideration different track gauge required for curvature and gauge transitions between tangent track and curved track.

d. Samples – A production sample of the crossing panel to be used in the grade crossing shall be supplied to the MBTA for inspection.

Part 2 – Products

2.01 General

Lagless-type, full depth modular rubber/neoprene road crossing system designed for mainline track. System characteristics shall include, but not be necessarily limited to:

a. Modular panels (3 units – 1 gage and 2 field) which, when assembled against two rails mounted on crossties, total nine feet in width.

b. Panels shall be designed for use with wooden crossties with resilient fastener tie plates, resilient fasteners (Pandrol-type) and 115 RE rail.

c. Crossing panels shall be insulated to retard stray current. Crossing modular material shall provide volume resistivity of 1 x 10^7 ohm-cm in accordance with the latest edition of ASTM D257.

d. Crossing material must be paintable with standard traffic marking paint.

e. Crossing material design shall accommodate the horizontal curved alignment indicated on the Plans.

2.02 Grade Crossing Surface

a. New, prefabricated modular panels without modifications to the manufacturer's standard design except as approved by the Engineer.

b. The running surface of each fully installed panel shall be flush with the top of rail.

c. Field-side crossing panels must have a continuous vertical surface from the top of the panel to the top of the ties to interface with and retain the adjacent paving material. A rail grinding relief area must be incorporated into the panel design adjacent to the rail head.

d. Crossing panels must be readily removable and reinstallable with standard hand tools without causing any damage to the panels. Crossing design shall allow for removing and reinstalling the crossing panels without requiring any new materials.

e. Crossing surface must be skid resistant to rubber vehicle tires and pedestrians; crossing surface must be highly resistant to chemicals and organic solvents.

2.03 Grade Crossing Panels

a. Crossing panels shall be one-piece modular units that do not require shims to support them.

b. Crossing panels shall provide clearance for the rail fastening system specified herein. Panel design shall provide for full bearing on the crosstie surface except at the rail fastener, as shown. Refer to MBTA Plan No. for typical crossing section.

c. Panels shall be designed as an interlocking system (i.e. tongue and groove) to provide a smooth, continuous surface or a secured hold-down at every tie positioned to control the corner areas.

d. Panels shall be designed to fit securely under the railhead, against the web of the rail on both the gage and field sides. Track gauge to be 56-1/2" measured between the inside faces of the running rails, 5/8" below the plane of the tops of the running rails.

e. Flangeways on each side of the gage panels to be no greater than 2" wide and no less than 1-1/2" deep.

f. Steel reinforced crossing panels must have no reinforcement within 1-1/2" of any surface.

g. Crossing panels shall be the "lagless" type.

2.04 Other Crossing Components

Each crossing package shall include, in addition to the rubber panels specified herein, all associated hardware, parts and/or specialized tools or equipment for a complete installation, including:

a. Tapered modular galvanized steel plates or other approved means to finish both ends of each crossing to prevent damage to the crossing panels from equipment being dragged by or hanging from passing trains.

b. Durable galvanized hardware for attachment of end plates/protectors to the crossing panels and to the wooden crossties.

c. Any special tools or equipment necessary to handle and/or install the crossing panels.

There shall be no rail-to-ground connection or rail-to-rail connection that could provide a path for electricity to go to ground.

2.05 Bituminous Paving Materials

Where indicated on the Plans, supply and install bituminous concrete base pavement materials in the strip between the field side panels between the tracks. Pavement to be in accordance with the Specification for Bituminous Concrete Pavement in the Book of Standard Track Material and Construction Specifications.

2.06 Rail Coating

Install a bitumastic coal tar coating to all rails (excluding top surface and gauge face), spacer block assemblies (if any), bolts, washers, fasteners and tie plates throughout the area where the grade crossing panels are to be installed.

Prior to coating, all steel surfaces are to be cleaned of dirt, loose rust, rust residue, loose mill scale, oil and grease to the Engineer's satisfaction. Surfaces shall not be coated less than 48 hours prior to crossing panel installation.

Part 3 – Execution

3.01 Installation

a. Construct grade crossings to the alignment indicated on the Plans and in accordance with the requirements of the AREMA General Specification for Highway Grade Crossings over Railroad Tracks and the AREMA Specification for the Construction of Bituminous Crossings, except as those Specifications may be modified herein.

b. Install the crossing in strict accordance with the manufacturer's instructions and installation procedure. Space crossties within the crossing limits in accordance with the requirements specified by the manufacturer. Should there be a conflict between the manufacturer's required tie spacing and the tie spacing shown in the Plans, the Engineer shall approve the final installed tie spacing.

c. Construct bituminous concrete, if applicable, to the depths shown on the Plans and in accordance with the MBTA Specification for Bituminous Concrete Paving.

1. Surface Course: In accordance with MBTA Spec. except that upon completion, the surface shall be smooth and true to indicated lines and grades.

d. The rails throughout the crossing limits and approaches shall be continuously welded by thermite welding or electric flash-butt welding. Welds shall be ground to within 0.010" of the parent metal to facilitate crossing installation.

e. Coat all exposed steel surfaces beneath the rubber crossing panels as specified in 2.06 herein.

Part 4 – Measurement and Payment

4.01 Measurement

a. Measurement for full-depth rubber grade crossings will be based on a linear foot basis. All preparation and incidental work necessary to complete the installation, including all related components, will be considered incidental to the unit price, complete-in-place.

b. Crossings with a combination of rubber rail seal and full-depth rubber will be measured on a linear track foot basis measured along the centerline of track for each linear foot installed to the limits shown on the Plans.

4.02 Payment

a. Payment for full-depth rubber grade crossings will be paid for at the Contract unit price for the quantities determined as specified above.

b. Crossings comprised of a combination of full-depth rubber panels and rubber rail seal will be paid at the Contract unit price for the quantities determined as specified above and paid for under Item 0290.026 Grade Crossing.

4.03 Payment Items

Item	Description	Unit
0290.021	Rubber Grade Crossing	LF
0290.026	Grade Crossing	LF

END OF SECTION

G. Rubber Rail Seal Crossing

Part 1 – General

1.01 Quality Assurance

a. All work associated with grade crossing design, construction and material procurement for grade crossing construction will be in conformance with all applicable sections in the MBTA Book of Standard Trackwork Plans, the Book of Standard Track Material and Construction Specifications and the Transit Design Standards Manual.

b. All codes and regulations of the municipal authorities within whose jurisdiction the installation of the crossing will take place shall apply. In addition, the standards and specifications of any utilities whose facilities may be impacted by crossing work shall also apply.

1.02 Submittals

a. Shop Drawings – Submit for approval, within 30 days of receiving the Notice to Proceed from the MBTA, details of the crossing system proposed to be installed. Included must be the rubber rail seal manufacturer's literature in which drawings and detailed installation instructions may be found.

b. Working Drawings – Submit detailed information about any proposed modification to the standard rubber rail seal configuration indicated on MBTA Plan No. . Such modifications would include, but would not be limited to, different tie spacing.

c. Submit for approval, if required by the Engineer, a tie layout plan showing the tie spacing, tie length and track gauge for each tie. Tie layout plan must take into consideration different track gauge required for curvature and gauge transitions between tangent track and curved track.

d. Samples – A production sample of the rubber rail seal to be used in the grade crossing shall be supplied to the MBTA for inspection.

Part 2 – Products

2.01 General

Modular virgin rubber/neoprene road crossing system designed for mainline track. System characteristics shall include, but not be necessarily limited to:

a. Modular units, consisting of gage side and field side strips designed for use with wooden crossties with resilient fastener tie plates, resilient fasteners (Pandrol-type) and 115 RE rail.

b. Rubber rail seal shall be insulated to retard stray current. Crossing material shall provide volume resistivity of 1 x 10^7 ohm-cm in accordance with the latest edition of ASTM D257.

c. There shall be no rail-to-ground connection or rail-to-rail connection that could provide a path for electricity to go to ground.

d. Crossing material must be paintable with standard traffic marking paint.

e. Crossing material design shall accommodate the horizontal curved alignment indicated on the Plans.

2.02 Grade Crossing Surface

a. New, prefabricated modular rail seal strips without modifications to the manufacturer's standard design except as approved by the Engineer.

b. The running surface of each fully installed rail seal strip shall be flush with the top of rail.

c. Both gage side and field-side rail seal strips, on the side facing away from the rail to which they are adjacent, must have a continuous vertical surface from the top of the strip to the top of the ties to interface with and retain the adjacent paving material.

d. Rail seal strips must be readily removable and reinstallable with standard hand tools without causing any damage to the rail seal.

e. Rail seal surface must be skid resistant to rubber vehicle tires and pedestrians; surface must be highly resistant to chemicals and organic solvents.

2.03 Rail Seal Strips

a. Rail seal strips shall be one-piece modular units that do not require shims to support them.

b. Rail seal strips shall provide clearance for the rail fastening system specified herein. Design shall provide for full bearing on the crosstie surface except at the rail fastener, as shown. Refer to MBTA Plan No. for typical crossing section.

c. Rail seal shall be designed as an interlocking system (i.e. tongue and groove) to provide a smooth, continuous surface or a secured hold-down at every rail seal joint to prevent any differential vertical movement of the rail seal strips.

d. Rail seal shall be designed to fit securely under the railhead, against the web of the rail on both the gage and field sides. Track gauge to be 56-1/2" measured between the inside faces of the running rails, 5/8" below the plane of the tops of the running rails.

e. Flangeways on the rail side of the gage side rail seal strips to be no greater than 2" wide and no less than 1-1/2" deep.

2.04 Other Crossing Components

Each crossing package shall include, in addition to the rubber rail seal specified herein, all associated hardware, parts and/or specialized tools or equipment for a complete installation, including:

a. A system for positively locking the rail seal strips together to create one continuous longitudinal surface (reference 2.03 c).

b. A clamping system generating   lbs. of spring compression to hold both gage and field side rail seal securely against the rail during and after installation.

c. Any special tools or equipment necessary to handle and/or install the rail seal units or the clamping system specified herein.

2.05 Bituminous Paving Materials

Where indicated on the Plans, supply and install bituminous concrete base pavement materials in the areas between the field side rail seal strips between the tracks. Pavement to be in accordance with the Specification for Bituminous Concrete Pavement in the Book of Standard Track Material and Construction Specifications.

2.06 Rail Coating

Install a bitumastic coal tar coating to all rails (excluding top surface and gauge face), spacer block assemblies (if any), bolts, washers, fasteners and tie plates throughout the area where the rubber rail seal is to be installed.

Prior to coating, all steel surfaces are to be cleaned of dirt, loose rust, rust residue, loose mill scale, oil and grease to the Engineer's satisfaction. Surfaces shall not be coated less than 48 hours prior to crossing panel installation.

Part 3 – Execution

3.02 Installation

f. Construct grade crossings to the alignment indicated on the Plans and in accordance with the requirements of the AREMA General Specification for Highway Grade Crossings over Railroad Tracks and the AREMA Specification for the Construction of Bituminous Crossings, except as those Specifications may be modified herein.

g. Install the crossing in strict accordance with the manufacturer's instructions and installation procedure. Space crossties within the crossing limits in accordance with the requirements specified by the manufacturer. Should there be a conflict between the manufacturer's required tie spacing and the tie spacing shown in the Plans, the Engineer shall approve the final installed tie spacing.

h. Construct bituminous concrete, if applicable, to the depths shown on the Plans and in accordance with the MBTA Specification for Bituminous Concrete Paving.

   2. Surface Course: In accordance with MBTA Spec. except that upon completion, the surface shall be smooth and true to indicated lines and grades.

i. The rails throughout the crossing limits and approaches shall be continuously welded by thermite welding or electric flash-butt welding. Welds shall be ground to within 0.010" of the parent metal to facilitate crossing installation.

j. Coat all exposed steel surfaces beneath the rubber crossing panels as specified in 2.06 herein.

Part 4 – Measurement and Payment

4.01 Measurement

a. Measurement for full-depth rubber grade crossings will be based on a linear foot basis. All preparation and incidental work necessary to complete the installation, including all related components, will be considered incidental to the unit price, complete-in-place.

b. Crossings with a combination of rubber rail seal and full-depth rubber will be measured on a linear track foot basis measured along the centerline of track for each linear foot installed to the limits shown on the Plans.

4.02 Payment

a. Payment for full-depth rubber grade crossings will be paid for at the Contract unit price for the quantities determined as specified above.

c. Crossings comprised of a combination of full-depth rubber panels and rubber rail seal will be paid at the Contract unit price for the quantities determined as specified above and paid for under Item 0290.026 Grade Crossing.

4.03 Payment Items

Item	Description	Unit
0290.021	Rubber Grade Crossing	LF
0290.026	Grade Crossing	LF

END OF SECTION