Chapter 7

HIGHWAY STRUCTURES

Introduction

The term “Highway Structure” generally refers to bridges but for highway designers, roadway pavements also fall within this category. A number of other structures included in highway projects are also considered “Highway Structures”. These include, but are not limited to: retaining walls, small box culverts, large pipe headwalls, high-mast light poles, ITS devices, reinforced soil slopes, sound abatement walls, overhead signs, traffic signals, and water quality basins of various types for treatment of stormwater.

The Bureau of Bridge Design usually designs bridges, overhead sign structures, sound abatement walls, and retaining walls. The Bureau of Traffic usually designs traffic signals. The Bureau of Materials and Research usually designs roadway pavements, reinforced slopes, and assists in the foundation design of bridges, overhead sign structures, sound abatement walls, traffic signals, ITS devices and other structures. Some considerations that the highway designer should be aware of in regard to “Highway Structures” are explained in this chapter.

General Procedure

Early in the project development process (Chapter 2), the Designer will recognize the plan elements that require structure design. The lead-time needed to design bridges is the chief concern, in part, because additional survey as well as geotechnical information for foundation design must be obtained. Other structures such as overhead sign structures will not require as much lead time for design, but their locations should still be established as early as possible to allow completion of subsurface explorations and a geotechnical evaluation of the foundation and to indicate where right-of-way lines should be placed, or where easements may be required.

Early determination of lead-time requirements is made in the Preliminary Design phase. The turnover of plans to Final (or Consultant) Design will include the status of structure coordination.

Structure design may have considerable effect on the environmental evaluation. Coordination with the Bureau of Environment needs to begin at the Preliminary Design phase before survey is requested. If, at any time, environmental considerations affect the structural concept of bridges or other structures, the Bureau of Environment must be alerted immediately.

The Designer should be familiar with the *Standard Specifications for Road and Bridge Construction (1)*, Division 500 Structures, as well as the supplemental and addenda specifications dealing with structures. The highway designer will not be responsible for major bridge, retaining wall, or foundation designs, but must know the terminology and how these items fit into the total plan.

The Designer should check with the municipality (if appropriate) for design requirements of any structure if the maintenance responsibility is not to be assumed by the NHDOT.

Roadside Safety

Above ground structures should be located outside the clear zone if practical. If a structure is located within the clear zone, it should be protected by guardrail or other barriers. Sign bases within the clear zone must be breakaway type or be protected. The following references contain criteria for safety practices: the AASHTO publication, *Roadside Design Guide (2);* the FHWA publication, *Safety Design and Operational Practices for Streets and Highways (3);* the AASHTO publication, *Design and Operational Practices Related to Highway Safety a Participants Notebook (4);* and the AASHTO publication, *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals (5).*

Other roadside features, such as retaining walls or sound abatement walls, should also be considered early in the design process and placed outside the clear zone or protected as necessary. Consideration should be given for placement of structures beyond the clear zone to accommodate future planned roadway widening (i.e. considering a longer clear span of a bridge to accommodate an ultimate width for a 3 lane versus 2 lane roadway).

In addition to moving objects outside of the clear zone, a berm should be considered in front of overhead sign structure supports and ITS camera poles to minimize the potential hazard of the object falling within the travel lanes and to minimize the potential for damage to infrastructure. An earth berm should also be considered in front of sound abatement walls to allow for potential redirection of vehicles away from the sound abatement wall or regaining control of the vehicle. The berm should be considered during the design of the foundations and included in the cover over the foundations.

For additional information on Roadside Safety, see the Highway Design Manual, Chapter 11.

Bridge Design

Bridges, as defined by NH State Law RSA 234:2, are all structures greater than, or equal to 10 feet in span measured along the centerline of the roadway. (This includes multiple adjacent pipes or structures that are not separated by more than half of their diameter.) Bridge designs are proposed or reviewed by the Bureau of Bridge Design. Coordination between Highway Design and Bridge Design is stressed in earlier chapters and reemphasized in this chapter. Begin coordination early to provide sufficient lead-time. All preliminary coordination must be initiated through the appropriate Design Chief of Bridge Design. All transmittals to Bridge Design should be addressed in writing to the Design Chiefs of Bridge Design, with an attention to the Designer.

See the NHDOT *Bridge Design Manual (6)* for additional and/ or more detailed information relative to bridge design. See the NHDOT Highway Design Manual, Chapter 2 for a more detailed description of the required coordination efforts and the order/phase of design associated with the coordination efforts.

<u>Establishing Bridge Criteria</u>

The following criteria may be used for preliminary line and grade studies:

- Bridges should be placed on tangents when possible.
- Vertical curves shall be placed outside the bridge limits when possible.
- Bridge grades should be 1% or more, when feasible, for effective surface drainage and runoff of de-icing chemicals. In constrained areas, e.g., urban or environmentally sensitive areas, the bridge grade should not be less than 0.5%. For sag vertical curves and Type II crest vertical curves (see Chapter 4), the minimum instantaneous grade on the bridge should meet the above requirements. For Type I crest vertical curves, K values $\leq$ 32 should be used. This will ensure a minimum grade of approximately 0.5% about 50 feet from the crest.
- The minimum vertical clearance over Interstate highways and at Interstate interchanges is 16'-6". The minimum vertical clearance over all other highways is 14'-6". The minimum vertical clearance must be maintained across the full width and along the length of the over passed roadway. See Chapter 3 for additional information. If there is any doubt as to the clearance to be used, the issue should be resolved with the Highway Design Administrator.
- Structures over railroads should have 22'-6" minimum clearance unless otherwise stated by the Chief of Design Services. (See Chapter 3 for additional information.)
- Structures over waterways should clear a 100-year flood elevation by 1 foot of free board clearance. The "free-board" clearance is measured from the calculated or recorded high-water elevation, to the lowest point of the bridge superstructure.
- The effect of structures on sight distance (including bridge rail) must be analyzed early to avoid creating unsafe operating conditions.
- Avoid superelevation transitions on a bridge deck if possible. If a superelevation transition or runoff is located in the middle of a span, verify with the Bridge Designer that this does not create a negative camber in a beam. If possible, begin or end transitions off the structures or begin or end the transitions at the centerline of bearing of an abutment or pier.
- For deck structures, the cross slope of the travel way should continue to the curb if the shoulder width is 5 feet or less, rather than match any break in the approach superelevation. For shoulder widths wider than 5 feet, the cross slope should be broken on the high side (only) of a superelevated deck section, to match the cross slope of the approaches. This would prevent any water from traveling across the slope and potentially freezing.
- Low points of sag vertical curves or superelevation crossovers should be placed so these features occur outside the limits of the bridge deck and approach slab because of the objectionable appearance of a sag camber in a beam and installation of drainage structures.

- The deck overhang (distance from center of girder to edge of deck coping) dimension usually ranges from 2-3 feet.

Initial Bridge Plan Coordination

After Highway Design has determined that a bridge crossing is required, the preliminary line, grade, and typical section are forwarded to Bridge Design. For structures over waterways, a preliminary minimum profile elevation should be requested from Bridge Design, based on a hydraulic analysis and assumed structural depth. Bridge Design requests bridge surveys and, later, bridge borings. Bridge Design then prepares preliminary bridge plans for coordination with Highway Design and other agencies, as appropriate.

Highway Design reviews the preliminary bridge plans for general agreement with the highway plans, but in particular these items should be checked:

- State and Federal project numbers;
- Station and angle of crossing. Bridge Design should be given a copy of the SDR survey plot, along with the field book pages further describing the bridge area. Geometric data should be checked carefully, particularly if the alignment is curved through the bridge site;
- Horizontal alignments, typical section(s) and superelevation(s);
- Finished grade, original ground and location of profile grade line(s);
- Approach curbs, type of approach railing, sidewalk, fencing, roadway rail (or barrier) connection to the bridge rail and rail or other protection of piers and/or abutments;
- Typical sections of the facility to be crossed may be modified to match abutment design. Check the effect on drainage and check the approach slab effect on catch basins. Verify how stormwater from the bridge is drained (i.e. scuppers) and if additional drainage is required to accommodate stormwater from the bridge;
- Drainage proximity to piers;
- Adequate provision for utilities and lighting on the structure, including future utility considerations;
- Clearance to the roadway below the bridge work;
- Lowering of the over passed roadway, or altering the typical section may affect frost protection of abutment/pier footings;
- Coordination with the Bridge Design on the zone of intrusion and details of single slope barrier so that the pier or sound abatement wall designs and shoulder width designs can consider these details;
- Traffic control phasing, construction sequencing and construction access; and
- Utility needs or relocations.

- **Bridge Design shall be notified of any change made to any of the items listed above or any revision that will affect the bridge design.**

Final Bridge Plan Coordination

When detailed bridge plans have progressed sufficiently, they will be submitted to Highway Design again for review. The plans should be checked for general agreement with the highway plans, but in particular these items should be checked:

- Verify the alignment, profile and approach typical sections are consistent with the highway details;
- Sheet numbers and total sheets in the project;
- Summary of bridge quantities for use of roadway items. The estimated unit prices in the bridge portion of the estimate must match the unit prices used in the roadway portion;
- Earthwork pay limits near the bridge;
- Proximity of blasting required for roadway rock excavation near the existing or proposed bridge. (Special precautionary measures may be required due to the blasting operations.);
- Coordinate with the bridge designer to ensure that all work at the roadway/bridge interface area has been accounted for and that quantities are not duplicated or omitted;
- Roadway guardrail post proximity to pier/abutment footings;
- Traffic control phasing and construction sequencing. Coordinate with the Bureau of Construction for a constructability review and construction access viability; and
- Utility needs or relocations.

At the Preliminary PS&E phase, road plans, draft Prosecution of the Work (POW), draft Traffic Control Plan (TCP) narrative, and bridge plans should be coordinated with the Bureau of Bridge Design. Preliminary bridge items, quantities and unit prices will be forwarded to the Bureau of Highway Design.

Roadway and bridge estimates must be checked for duplicated items. If duplicate items exist, be sure to show a contract total on the appropriate roadway summary sheet and clearly depict it as ‘Not an Item Total’ in the appropriate location on the summary table.

Retaining Walls

Retaining walls are used in cut and fill locations where space does not permit an appropriate slope to extend to the original ground. There are several types described herein, but other systems, variations or combinations of systems may be considered when making comparative estimates. See the NHDOT Bridge Design Manual *(6)*, Chapter 6, Section 6.4 “Retaining Walls” for additional information. The latest version of the Bridge Design sample plans and manual can be found at http://www.nh.gov/dot/org/projectdevelopment/bridgedesign/documents.htm.

The need for a retaining wall should be recognized during the Preliminary Design phase and should be shown on the hearing plan. A length and height should be determined in coordination with Highway Design. The need for hand rail/guardrail at the tops of walls should be considered in the evaluation. Environmental and other site conditions sometimes influence the choice of wall types and therefore comparative estimates should be available for conceptual reviews as well as for engineering decisions.

A retaining wall design typically requires the input of Bridge Design, Highway Design and the Material and Research Bureaus. The design effort includes establishing the wall alignment and the top and bottom elevations; analyzing the external stability of the wall (i.e., sliding and overturning); analyzing the global stability (i.e. failure behind or below the wall); designing foundation treatments to support the wall; and providing the structural analysis and details for non-proprietary walls. The internal stability of proprietary retaining wall systems is provided by the manufacturer during the construction phase. While Highway Design may design smaller walls, the Bridge Design and Materials and Research Bureaus should be consulted to review the design. Other bureaus or external groups may be involved in approvals of wall appearance or right-of-way negotiations, so it is important to have sufficient lead time for design, review and decision making.

During the Preliminary Design phase, foundation, economic, environmental and right-of-way impacts are evaluated with the Bureau of Bridge Design, the Bureau of Materials and Research, and the Federal Highway Administration (FHWA) (overview projects only) to determine the type of structure to be used on the project.

Consider the following items for the layout and design of retaining walls:

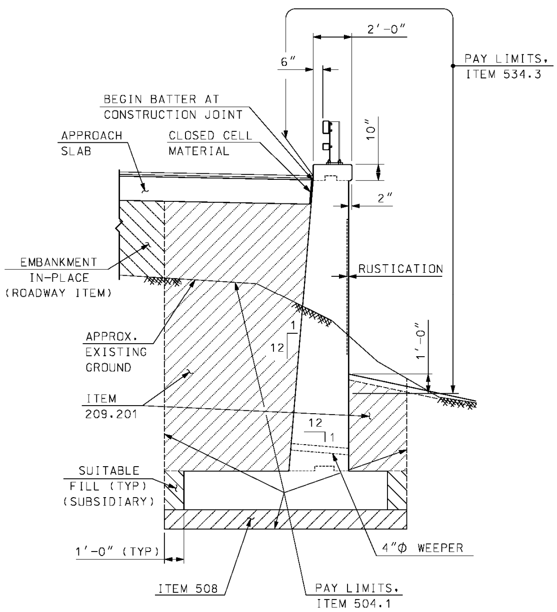
- Functional classification and applicable wall type options;
- Highway geometry;
- Design Clear Zone requirements;
- Amount of excavation required;
- Traffic characteristics;
- Constructability and traffic control;
- Impact to adjacent environmentally sensitive areas;
- Impact to adjacent structures or buildings;
- Potential added lanes;
- Length and height of wall;
- Limits of slope work or grading to match the wall into the surrounding area;
- Materials to be retained;
- Foundation support, external stability and potential for differential settlement;
- Groundwater and frost protection depth;
- Earthquake loads, if applicable;
- Right-of-way costs or need for construction easements;
- Risk;
- Overall cost;
- Guardrail or sound abatement wall posts/ foundation locations;
- Maintenance concerns;
- Utilities;
- Railroads;
- Land use above the wall (i.e. fencing needs); and

- Visual appearance.

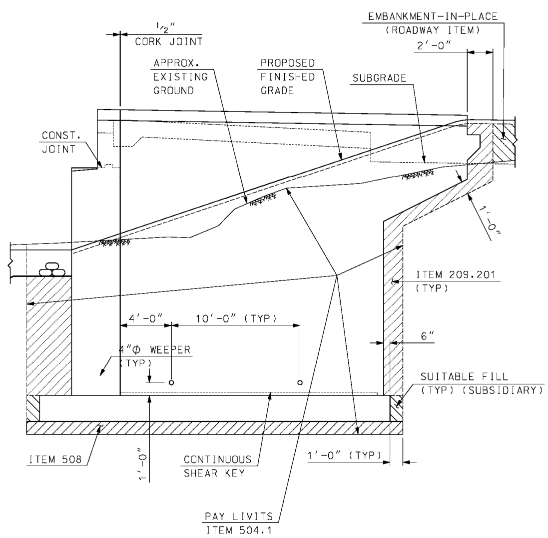
<u>Reinforced Concrete Walls</u>

Reinforced concrete walls usually consist of cantilever walls, which allow construction of taller and thinner walls. Figure 7-1 shows the general configuration of a cantilever wall. Dimensions and drainage provisions shown are approximate and are to be specified by the structural designer. The wall face can be surfaced with a variety of textures, patterns, colors and materials, which enhance its appearance and help it blend in with the surroundings. See the NHDOT Bridge Design Manual *(6)*, Chapter 2, Appendix 2.6 for examples of surface wall treatments.

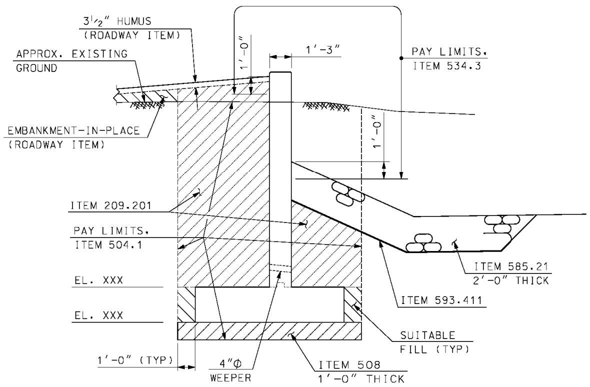
Figure 7-1
CONCRETE CANTILEVER RETAINING WALL
(Not to Scale)



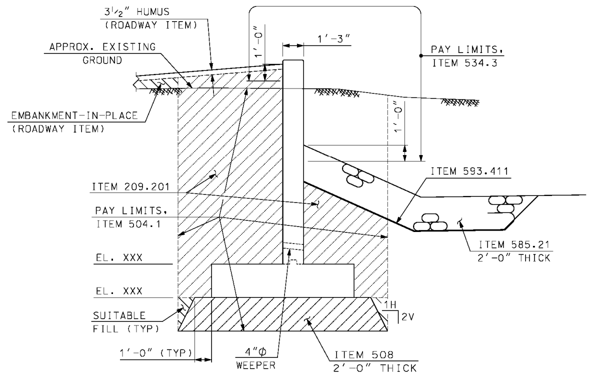
Typical Wing Section



Elevated U-Back with Butterfly



Typical Wall Section

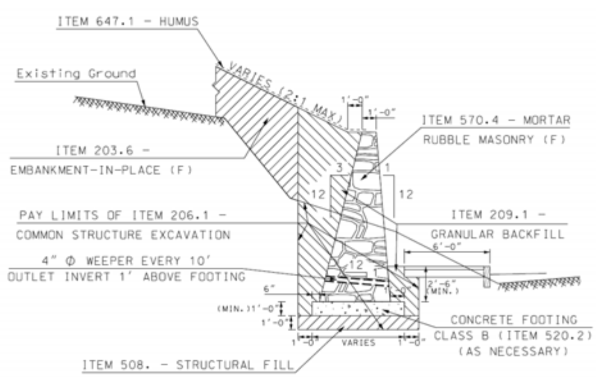


Typical Wall Section
Greater than 1 foot Structural Fill

Mortar Rubble Masonry Walls

Mortar Rubble Masonry (MRM) walls may be used in the same applications as those described for gravity walls except as a very high wall or to support very steep slopes. This type of wall is most commonly used in front of houses or other buildings at the back of sidewalks (see Figure 7-2) to prevent slope encroachments and for aesthetic enhancement. In some instances a form liner can be used with a mass concrete wall to mimic the MRM look in lieu of an actual MRM wall (see the Gravity Retaining Walls section for additional details).

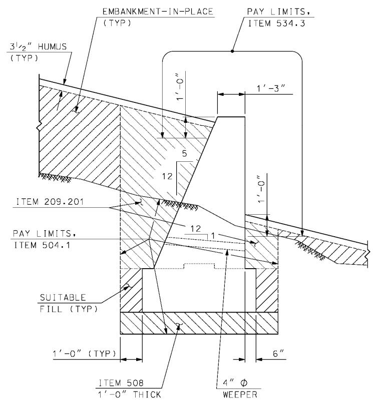
Figure 7-2
MORTAR RUBBLE MASONRY RETAINING WALL
(Not to Scale)



Concrete Gravity Retaining Walls

Concrete Gravity Retaining Walls are constructed with mass concrete and derive their capacity to resist lateral loads though the dead weight of the wall. These walls should not be used if their foundations cannot be designed to limit total and differential settlements to acceptable limits.

Figure 7-3
TYPICAL GRAVITY RETAINING WALL
(Not to Scale)



Mechanically Stabilized Earth Walls

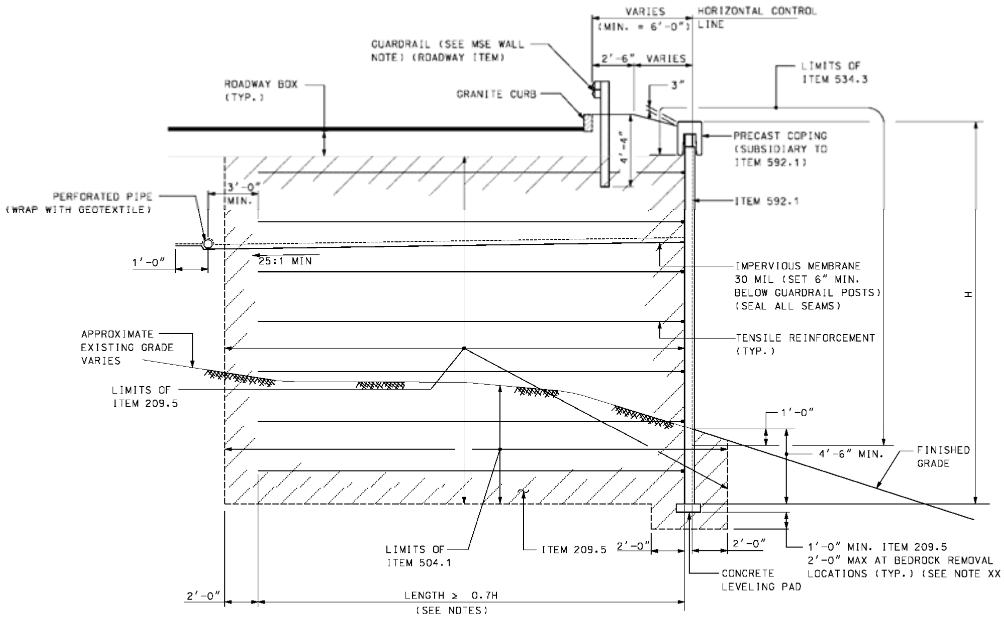
Mechanically Stabilized Earth (MSE) retaining walls employ metallic (inextensible) or polymeric (extensible) tensile reinforcements in the soil mass and a vertical or near-vertical facing element (see Figure 7-4). MSE retaining walls may be well suited where differential settlements are anticipated. MSE retaining walls are generally a lower cost alternative to reinforced concrete retaining walls. The facing for MSE walls include reinforced precast concrete panels and segmented concrete blocks. MSE walls are proprietary systems that require approval by the Department's Retaining Wall Committee. The Bureau of Bridge Design maintains a list of approved MSE wall systems along with any limitations or restrictions for a particular wall system. A special provision (Section 592) for MSE walls and a special provision (Item 209.5) for modified granular backfill are required.

MSE retaining walls should not be used when utilities, drainage, or other roadway features must be constructed within the reinforced zone (however limited intrusion of these features may be allowed after evaluation), when floodplain erosion may undermine the reinforced fill zone, or where the depth of scour cannot be reliably determined. Coordination of guardrail and sound abatement wall posts and foundations shall occur to ensure correct spacing is achieved for the selected retaining wall type.

Figure 7-4

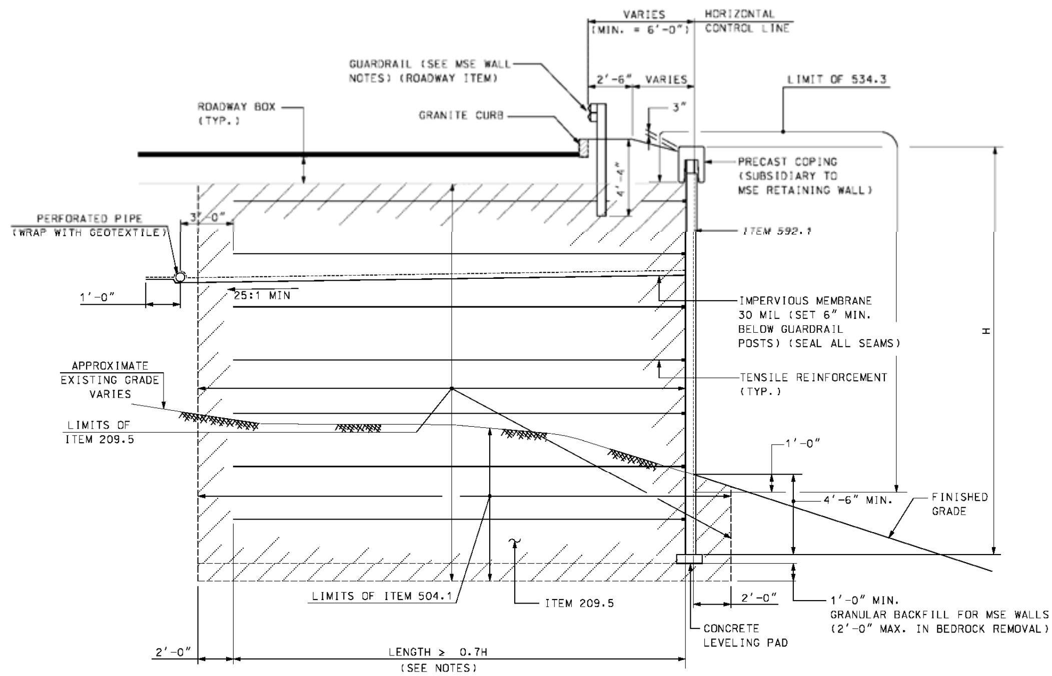
TYPICAL MSE WALLS

(Not to Scale)

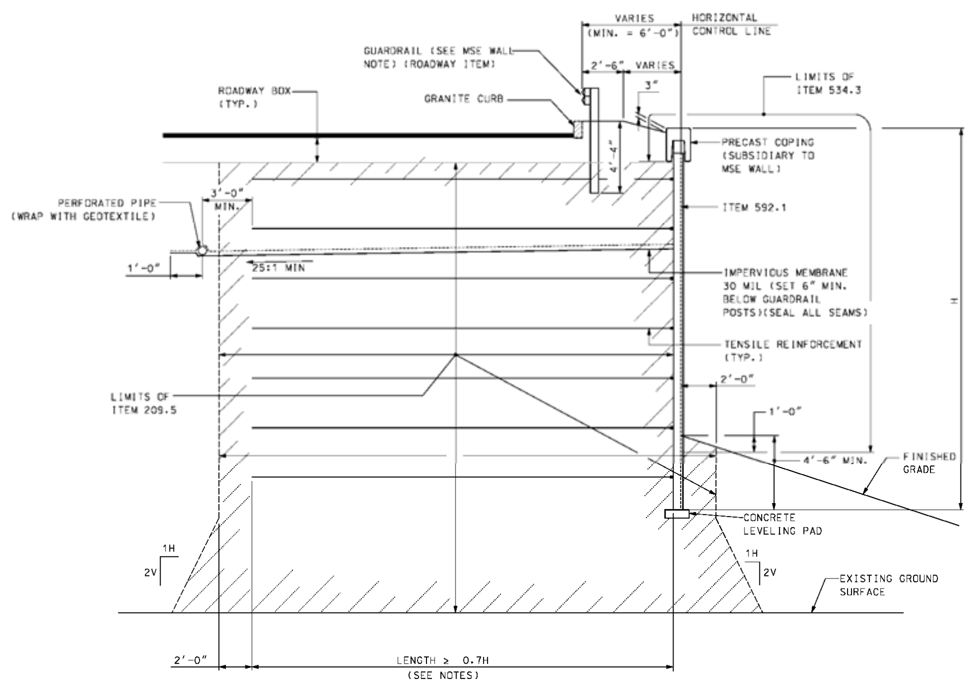


Typical for MSE Wing Wall in Cut with Granular Backfill Below Leveling Pad Only

Figure 7-4
TYPICAL MSE WALLS
(Not to Scale)

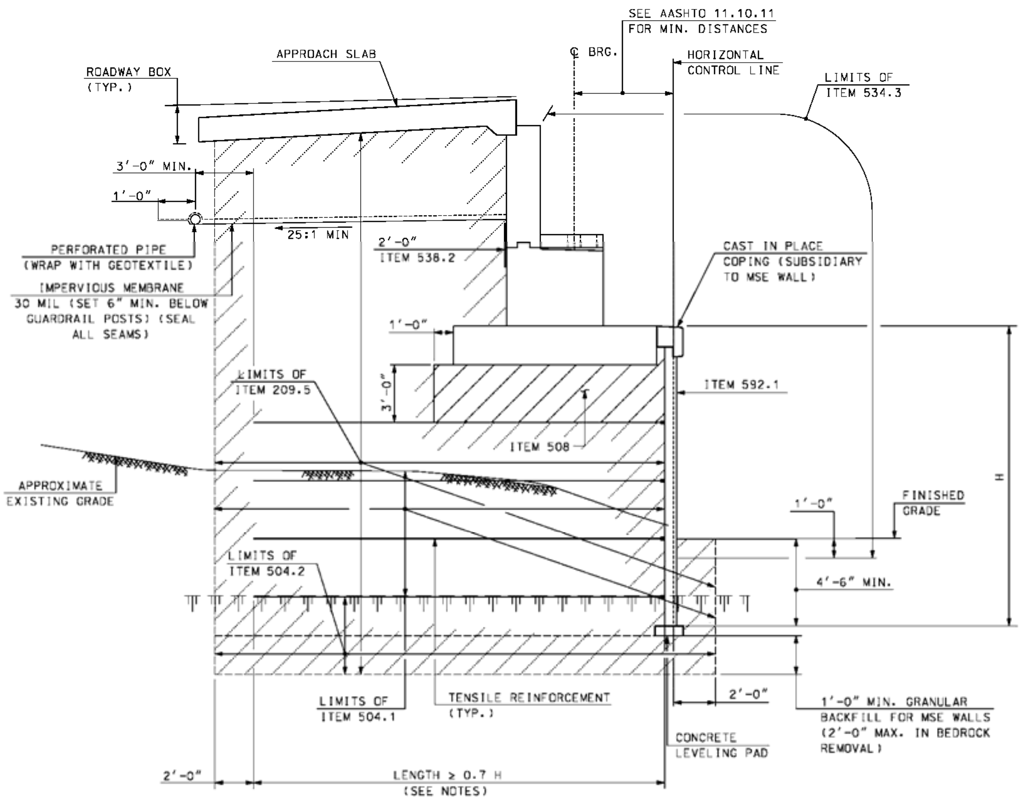


Typical for MSE Wing Wall in Cut with Full Width Layer of Granular Backfill Below Wall



Typical MSE Wall Section in Fill

Figure 7-4
TYPICAL MSE WALLS
(Not to Scale)



Typical Abutment Section on MSE Wall

<u>Prefabricated Modular Gravity Walls</u>

<u>Bin/Crib Walls</u>

These walls are constructed with interlocking beams of precast concrete, steel, aluminum, or treated timber that are filled with either earth or stone. The chief advantages are flexibility and comparatively low cost. Figure 7-5 shows an example of the bin/crib walls.

<u>Gabion Walls</u>

Gabions are a specific type of bin wall that employ wire mesh baskets filled with rock fragments as shown in Figure 7-5. Although gabions can be used for retaining walls, the more common use is for erosion control where poor base soils or washouts suggest a flexible structure. A special provision (Section 584) is required for gabion walls.

<u>Segmented Concrete Block Walls</u>

These walls consist of interconnected, small, unreinforced, precast concrete blocks that are generally used for shorter wall height applications. For wall heights greater than a few feet MSE tensile reinforcement would be required. These wall systems require approval by the

Department's Retaining Wall Committee. See the MSE wall section for more information.

Precast Concrete Modular (PCM) Walls

These walls consist of large, reinforced precast concrete modules that are backfilled with granular backfill. PCM walls are proprietary systems that require approval by the Department's Retaining Wall Committee. The Bureau of Bridge Design maintains a list of approved PCM wall systems along with any limitations or restrictions in their use. A special provision (Section 592) is required for PCM walls.

Figure 7-5
PREFABRICATED MODULAR GRAVITY WALL TYPES
(Not to Scale)

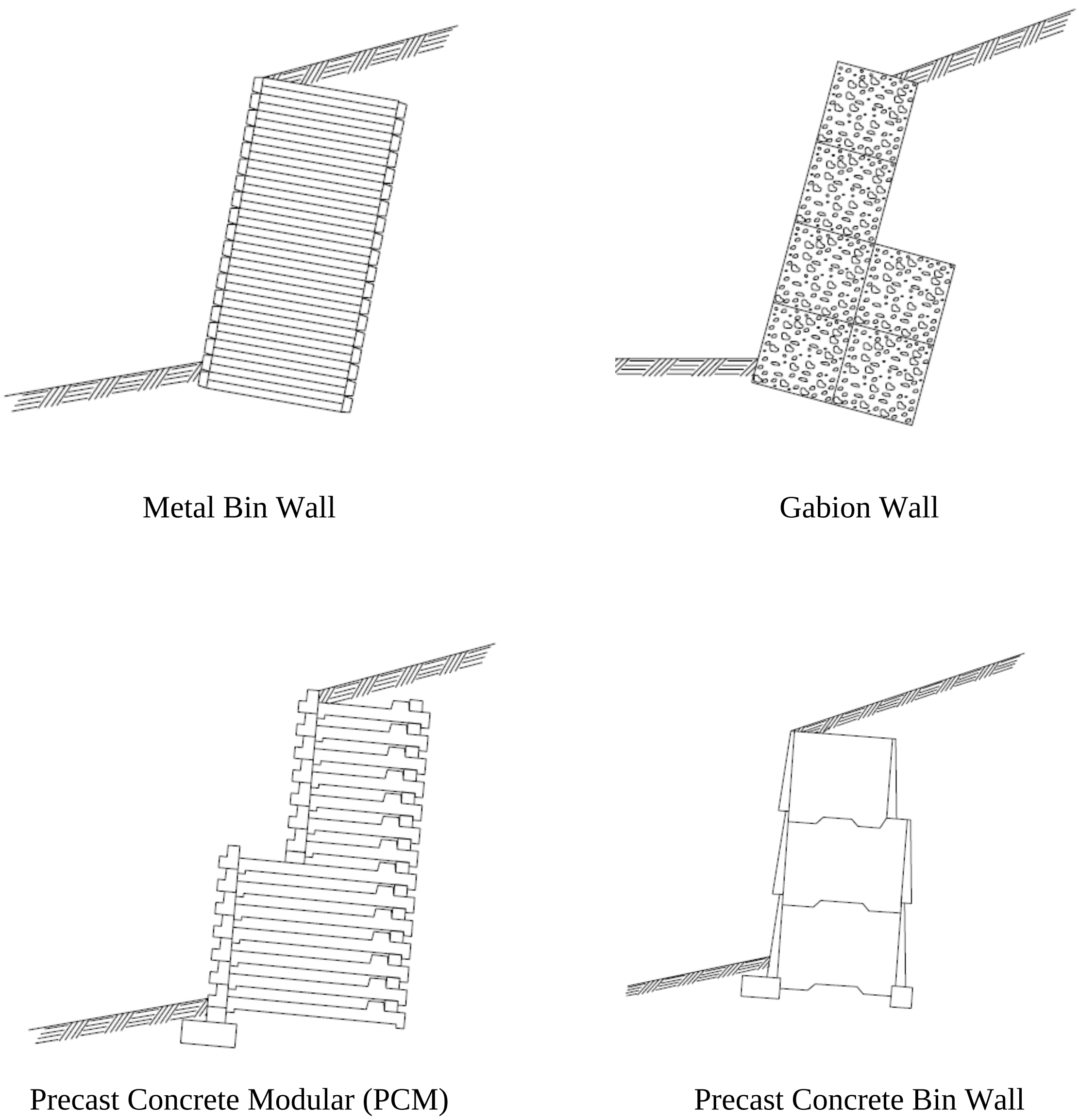
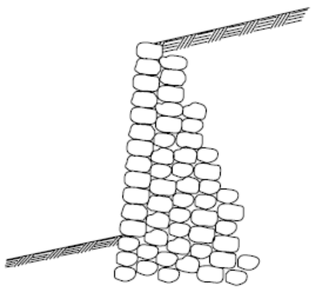
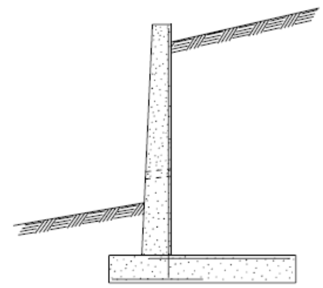


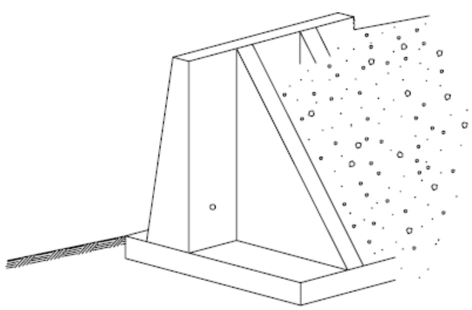
Figure 7-6
RIGID GRAVITY, SEMIGRAVITY CANTILEVER, NONGRAVITY CANTILEVER, AND ANCHORED WALL TYPES
(Not to Scale)



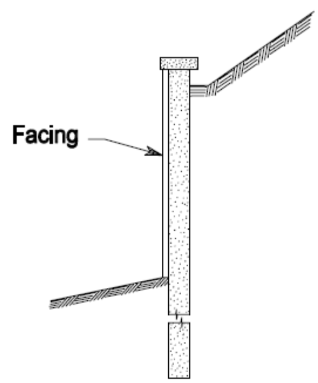
Mortar Rubble Masonry
Ridgid Gravity Wall



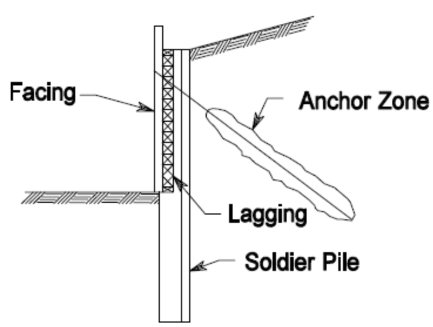
Reinforced Concrete Cantilever
Semigravity Wall



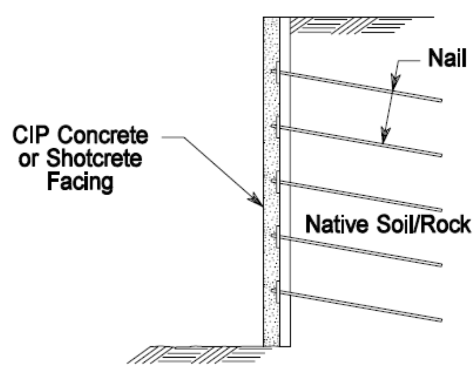
Reinforced Concrete Counterfort
Semigravity Wall



Slurry or Cylinder Pile
Nongravity Cantilever Wall



Soldier Pile Tieback Wall

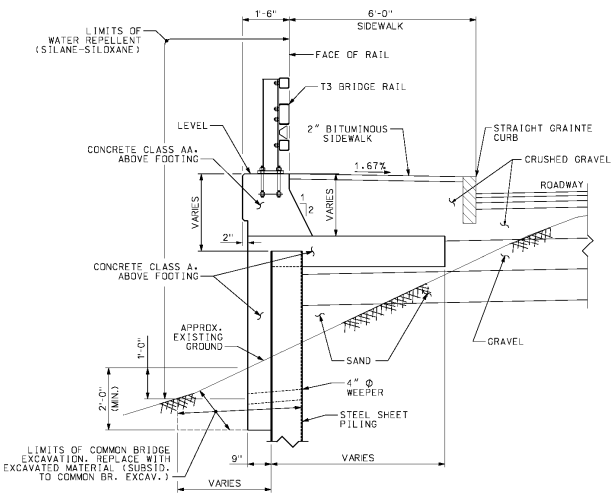


Soil Nail Wall
in Cut

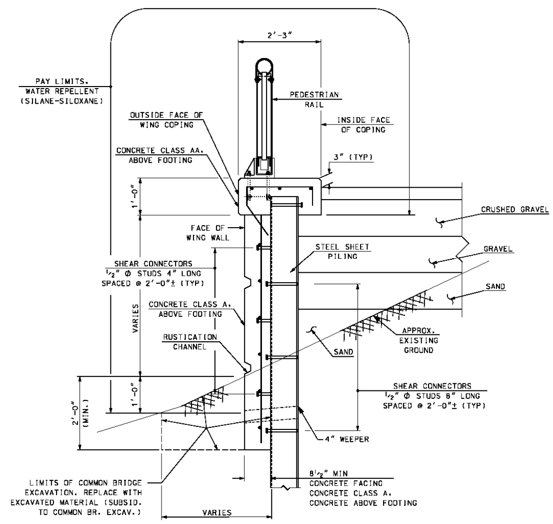
Steel Sheet Pile Walls

Steel sheet walls shown in Figure 7-7 require site conditions where sufficient embedment of the sheets below the wall face can be achieved to provide adequate stability. Steel sheet pile walls that have a large exposed height may require additional support by anchors. This type of wall may be faced with reinforced concrete. These walls are beneficial in steep slopes and where temporary excavation behind the wall is difficult.

Figure 7-7
TYPICAL STEEL SHEET PILE WALLS
(Not to Scale)



Typical Steel Sheet Pile Retaining Wall with Bridge Rail Moment Slab



Typical Steel Sheet Pile Retaining Wall with Architectural Treatment

Drainage Structure Headwalls

Large drainage pipes require headwalls for support, erosion prevention, and occasionally for hydraulic efficiency. The headwalls shown in the Standard Plans will normally be adequate for most designs. If a special design is required for hydraulic entrance efficiency or energy dissipation at the outlet end, the Hydraulics Section should be consulted.

Sound Abatement Walls and Berms

Noise abatement in New Hampshire is generally in the form of a sound abatement wall or an earth berm. The locations of these barriers are carefully selected based on their ability to meet a set of specific criteria set forth by the NHDOT and FHWA, see Chapter 11 for additional information. An area is not considered eligible unless it meets all of the criteria in the Department's Noise Policy:

http://www.nh.gov/dot/org/projectdevelopment/environment/units/program-management/documents/2011NHDOTNoisePolicy.pdf.

The location of a sound abatement wall or berm is determined by the highway designer in coordination with the environmental Air and Noise Program Manager to obtain the required noise abatement. Sound abatement structures should be located outside the clear zone if sufficient corridor width is available or protected by a barrier system, and must be located within the right-of-way for future maintenance. In space restricted areas, a combined, integral, vehicular barrier and sound abatement wall system may be required. The location and design of sound barriers must consider all of the other roadway, structure and environmental resources within the project.

The design of sound abatement walls should consider maintenance and aesthetics. Where walls are positioned significantly away from the roadway, a maintenance road adjacent to the wall should be considered. These maintenance roads are typically constructed with select materials with humus and seed placed over the roadway. In some instances access doors for maintenance are also required. Aesthetically, the walls should avoid abrupt changes in direction and in the top line of the wall profile. See the sound abatement wall detail sheets relative to maximum vertical steps for the walls.

There are many different types of sound abatement walls. The most common type of sound abatement wall is the wood panel (timber) wall with drilled shaft foundations. The Bureau of Bridge Design has developed standard timber sound abatement wall details, including their foundation configurations (except for shaft depths). These details should be useable for all timber sound abatement walls less than 25 feet in height with minor plan changes; Bridge Design should be consulted to verify the selected wall can be used. These details can be found on online at: http://www.nh.gov/dot/org/projectdevelopment/bridgedesign/detailsheets/index.htm.

The drilled shaft lengths cannot be standardized because of variations in subsurface conditions and ground surface topography along the wall. The Bureau of Materials and Research should be contacted to perform a subsurface investigation and to design the drilled shaft lengths once the sound abatement wall location, wall heights and cross section geometry have been determined and finalized. A special provision (Section 509) is required for the drilled shaft construction.

Sign, Light, Signal, and ITS Supports

The structures for breakaway signs, luminaries, and traffic signals are usually standard items, designed by the manufacturer and approved for NHDOT use by FHWA. Most foundations for these appurtenances are standard designs approved for normal soil conditions and some are shown in the *Standard Plans for Road and Bridge Construction (9)*. Refer to AASHTO publication, *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals (5)* for additional details.

The preliminary foundation design for high-mast lighting, overhead sign structures, or other heavy steel supports is provided by the Bureau of Bridge Design during the design phase. The Bureau of Materials and Research is involved in the preliminary designs when subsurface information is needed and/or foundation recommendations are needed. This allows an estimated quantity to be included in the contract plans. The final design of these foundations are completed by the Contractor and reviewed and approved by the Bureau of Bridge Design. The designer should be aware of the preliminary dimensions to avoid conflicts with new or existing underground installations and the potential hazards for vehicles if the foundation is within the clear zone. (See the NHDOT Bridge Design Manual *(6)*, Chapter 10, Section 10.3, "Overhead Sign Structures" for design requirements and coordination.) Signal supports, although they are considered a fixed obstruction, are allowed within the clear zone without requiring protection by barrier (they can be placed a minimum of 7 feet from the edge of pavement with guardrail or curb and 10 feet without guardrail or curb). Consult the *Manual on Uniform Traffic Control Devices* (MUTCD) *(10)*, Section 4D, "Lateral Offsets of Signal Supports and Cabinets" for additional guidance.

The placement of Intelligent Transportation Systems such as Closed Circuit Television Cameras (CCTV), Dynamic Message Signs (DMS), Variable Speed Limit Signs (VSL) and Road and Weather Information Stations (RWIS) is determined by the Transportation Systems Management and Operations Center (TSMO). The support structures and foundations for CCTV and DMS are designed by the Bureaus of Bridge Design and Materials and Research. Support structures and foundations for RWIS are designed by the Contractor. For additional details on design responsibilities and coordination during construction, see the Bridge Design Manual, Chapter 10 on line at: http://www.nh.gov/dot/org/projectdevelopment/bridgedesign/documents.htm.

Reinforced Soil Slopes

A reinforced soil slope (RSS) consists of regularly spaced layers of extensible reinforcement (i.e. geogrid) placed horizontally in the embankment fill to a depth (or length) necessary to satisfy internal and global stability requirements. A RSS is generally considered for a fill slope that is steeper than 1-1/2H:1V. Backfill for the RSS is granular backfill (Item 209.4). A RSS is a possible alternative to a retaining wall and is particularly well-suited where settlement is anticipated and foundation excavations are difficult. A RSS should not be used where utilities, drainage or other feature must be constructed within the reinforced zone unless their installation can be adequately coordinated. Guardrail, fence posts and other similar features can be installed within the reinforced soil zone, but must be accounted for in the design. A vegetative facing for the RSS can be provided, but requires special details that depend upon the slope angle. A RSS should be designed or reviewed by the Bureau of Materials and Research.

Roadway Pavement Structure

The roadway pavement structure is the combination of base courses (e.g., sand, gravel, crushed gravel, crushed stone coarse, crushed stone fine) and surface courses (i.e. pavement) necessary to support traffic loads and distribute it to the subgrade or roadbed.

The process for determining the pavement structural components is described briefly in Chapter 4, Alignment and Typical Sections. The process requires that the Bureau of Highway Design prepare an analysis based upon the Average Daily Load (ADL) furnished by the Bureau of Traffic, coordinate with the Bureau of Materials and Research, and obtain approvals from FHWA as part of the PS&E process. To request a formal Pavement Recommendation, see Chapter 2.

The pavement structure design is based upon the variables of ADL, Regional Factor, Soil Support Value, Structural Layer Coefficient, frost penetration, and material availability. There are other factors affecting pavement structure decisions, which may override the technical conclusions of the designer, therefore the recommended structural design is tentative until it has final approval from the Highway Design Chief.

Appendix 7-1 is shown as a reference guide. The designer's conclusions are subject to review until the design is approved. (Note: The AASHTO Chart 400-2 referred to in Appendix 7-1 is contained in the *1972 Interim Guide for the Design of Pavement Structures (7)*.

Pavement can also be reclaimed by scarifying the existing pavement, if necessary, and pulverizing the existing pavement together with base course materials, or additional stone. This process is called full depth reclamation (FDR). The homogeneous mixture is graded, compacted, and then new pavement is placed. For FDR it should be noted that the material will be increased in depth by a "fluff" factor of about 10%, so if a 12" reclaimed stabilized base were specified, the material, after reclamation, would be about 13.2" thick. Including the depth of the new pavement this could increase the overall depth of the structural section significantly. FDR results in an increase in grade and the designer should be aware of any issues that elevation changes could present relative to guardrail heights, drainage, driveway matches, wetland permitting, traffic control, etc. FDR is not applicable for every roadway and every project. Asphalt coring with base course sampling must be performed to evaluate the existing pavement structure and the soils below the pavement to determine if FDR is applicable. Coring and sampling is performed as part of the Pavement Recommendation.

Another alternative to FDR is called a "sandwich" treatment. This treatment consists of placing 8 to 12 inches of crushed gravel over the existing pavement and repaving with a new binder and wearing course thus creating a "sandwich". In some cases, a mixture of gravel and cold plane millings (RAP) or just millings (RAP) may be used in lieu of crushed gravel. The millings (RAP) generally require processing (crushing and screening) before they can be used. This treatment also increases the grade so impacts to existing structures must also be considered but it should be considered as an option on projects where FDR is not applicable.

Combinations of cold plane and repave and inlay and overlays are effective treatments that may be used to address cracking, rutting, delamination, and other surface distresses. Cold planing (milling) can also be used to restore curb reveals, particularly for urban streets where curb reveal decreases with each overlay. Often the cost of cold planing and replacing the existing wearing course is recovered by eliminating the need for raising curbs, catch basin grates, etc. The pavement that is removed from the milling can also be salvaged to the State and/or retained by the Contractor for use as RAP in the new mix. Close coordination is required between the Bureau of Highway Design, the Bureau of Materials and Research, the Bureau of Construction, and the Maintenance District Office to derive maximum benefits from cold plane and pave operations, proper salvage, and reuse of the millings (RAP).

For projects involving rehabilitation type treatments like cold plane and pave or remove and replace, the designer should consider salvaging the millings (RAP) or excavated pavement back to the State at the nearest District maintenance patrol shed. This material is valuable to the State and can be processed and mixed with virgin materials for use as shoulder gravel/backup, base courses for sandwich or box cuts, and cold mix pavement. A calculation needs to be performed to determine if there will be sufficient quantity of millings generated to make salvaging possible. The Contractor is allowed to retain enough millings to use as RAP in the production of the new mix. This amount is estimated at 30% of the total tonnage of new pavement on the project. Any excess above this amount may be salvaged to the State. The designer should quantify the salvageable amount and work with the District Maintenance Office to select the salvage location. The salvage location must be located within 10 miles of the project.

Additional information about recycling pavement is compiled in the FHWA publication, *Pavement Recycling: Executive Summary and Report (8).*

Wheel path rutting and pavement shoving can occur in areas of high traffic, large percentages of trucks, areas of tight turning radius, and hard vehicle braking. The use of high strength pavement (Item 403.1109) must be considered for these locations to prevent rutting and shoving from developing, or considered to rehabilitate an existing pavement. High strength pavement is produced at the hot mix plant by substituting a polymer modified binder (e.g. PG 76-28 or PG 64E-28) for the conventional binder (e.g. PG 58-28 or PG 64-28) that is typically used. High strength pavement does not entail a special mix design and for this reason it may be specified for all mix types including wearing course, binder, and bridge base. The use of high strength mix has increased over the years to the point where it is standard practice for signalized intersections, roundabouts, traffic circles, toll plazas, off ramps, collector distributor roads, on ramps, steep grades, and snowmobile crossings. In extreme applications, high strength is specified for both the binder and wearing courses. If the existing pavement exhibits rutting and shoving, cold planing must be performed to remove the failed pavement prior to replacing it with high strength.

Over the past 10 years or so the Department has been employing pavement preservation techniques to “keep good roads good”. Pavement preservation includes the timely application of preventative maintenance treatments such as micro surfacing, chip seals, bonded wearing course (Nova Chip™), thin lift hot mix asphalt (HMA) overlays, use of polymer modified binders and asphalt rubber modified binders, in place recycling methods (hot and cold), and crack sealing, to restore the roadway to new condition before more costly rehabilitation or reconstruction is required. The success of pavement preservation is highly dependent on applying the right treatment to the right road at the right time in order to maximize the financial benefit. Candidate/project selection, surface preparation, materials, and construction quality is of the upmost importance. Candidate selection and the use and applicability of these treatments is evaluated on a project specific basis by the Bureau of Materials and Research with specific recommendations being contained in the Pavement Recommendation report.

In addition to providing the recommended pavement structure and/or treatment, the Pavement Recommendation report also contains other project specific information such as the any coring and base course sampling that was performed, recommended asphalt binder grade(s), guidance with respect to the use of QC/QA (Item 403.1100X) versus Method Specifications (Item 403.11), level of QC/QA Ride Smoothness testing, the use of Pavement Joint Adhesive (Item 403.6) and Material Transfer Vehicle (MTV) (Item 403.4), the use of High Strength pavement (Item 403.1109), and any applicable Special Provisions that may be required for the project. The use of QC/QA or Method paving specifications should also be verified with the Bureau of Construction. The total tonnage of pavement should be evaluated to verify it meets the minimum quantity for QC/QA pavement, see section 403 of the Standard Specifications for more information.

References:

1. New Hampshire Department of Transportation (NHDOT), *Standard Specifications for Road and Bridge Construction*, NHDOT, 7 Hazen Drive, Concord, N.H., September 2010

2. American Association of State Highway and Transportation Officials, (AASHTO), *Roadside Design Guide*, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, D.C., 2011

3. Federal Highway Administration (FHWA), *Safety Design and Operational Practices for Streets and Highways*, TSR 80-228, FHWA, Washington, D.C., 1980

4. American Association of State Highway and Transportation Officials (AASHTO), *Design and Operational Practices Related to Highway Safety Participants Notebook*, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, D.C., Revised 1978

5. American Association of State Highway and Transportation Officials (AASHTO), *Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals*, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, D.C., Fifth Edition 2009

6. New Hampshire Department of Transportation (NHDOT), *Bridge Design Manual*, NHDOT, 7 Hazen Drive, Concord, N.H., October 1, 2000

7. American Association of State Highway and Transportation Officials (AASHTO), *1972 Interim Guide for the Design of Pavement Structures*, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, D.C., 1972

8. Federal Highway Administration (FHWA), *Pavement Recycling: Executive Summary and Report*, FHWA, Washington, D.C., 1996

9. New Hampshire Department of Transportation (NHDOT), *Standard Plans for Road Construction*, NHDOT, 7 Hazen Drive, Concord, N.H., July 2010

10. Federal Highway Administration (FHWA), *Manual on Uniform Traffic Control Devices*, FHWA, Washington, D.C., 2009 Edition

11. USACE Cold Regions Research and Engineering Laboratory (CRREL), *Special Report 94-30: Layer Coefficients for NHDOT Pavement Materials*, Hanover, N.H., September 1994