FINAL REPORT

GUIDELINES FOR THE USE, DESIGN, AND CONSTRUCTION OF BRIDGE APPROACH SLABS

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agency.)

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ABSTRACT

Differential settlement at the roadway/bridge interface typically results in an abrupt grade change, causing driver discomfort, impairing driver safety, and exerting a potentially excessive impact traffic loading on the abutment. Bridge approach slabs are used to keep the effects of this differential settlement within tolerable limits. In many cases, however, the final magnitude of settlement exceeds the working range of an approach slab, necessitating costly roadway and slab repairs.

Many state departments of transportation regard the settlement of bridge approach slabs as a substantial maintenance problem. Guidelines affecting the use, design methodology, material specifications, and construction techniques vary greatly from state to state. The purpose of this study was to provide a literature review on the subject and to conduct a survey on the state of the practice.

Thirty-nine state departments of transportation responded to the survey. Summary findings were compiled and compared with practices used by the Virginia Department of Transportation. Recommendations for a new set of guidelines, aimed at mitigating bridge approach settlement, were formulated.

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INTRODUCTION

Approach maintenance problems, manifested by a characteristic bump felt when driving onto or away from a bridge, cause an estimated $100 million in annual repair expenditures for state departments of transportation (DOTs) (Briaud et al., 1997). Although this problem is commonly recognized and its causes are clearly identified, no unified set of engineering solutions has emerged, primarily because of the number and complexity of the factors involved. Very seldom can settlement at bridge approaches be traced to a single cause. Typically, settlement reflects an aggregate effect of subsoil conditions, materials, construction techniques, drainage provisions, and quality control methods.

Settlement of roadway fills typically consists of a compression of the embankment material and a consolidation of the underlying natural foundation soils. The overall magnitude of these two components can be substantial. An abrupt change in grade often develops at bridge approaches because bridge foundations, normally piles or drilled shafts, must be designed for a negligible amount of settlement. The bump at the end of the bridge often creates driver discomfort. In addition, traffic impact loads acting on a structure increase the chances of damage to the abutment and the deck. The resulting repairs can be costly in terms of expended maintenance funds and impeded traffic flow to solve a recurring problem.

In an effort to reduce the effects of differential settlement, approach slabs are often constructed at the ends of bridges. They normally consist of concrete structural slabs supported at one end on the bridge abutment and at the other end on the embankment soil. In general, approach slabs deliver a smooth grade transition between the bridge and the roadway. In a large number of cases, however, their use results merely in moving the bump from the end of the bridge to the end of the approach slab. Consequently, various issues surrounding the need for and the construction of approach slabs have become the subject of controversial debates in the highway community.

PURPOSE AND SCOPE

The primary purpose of this study was to examine practices of various state DOTs regarding the use, design, and construction of approach slabs and compare them with those used by the Virginia Department of Transportation (VDOT). In addition, the researcher aimed to conduct a literature review of the issues involved and recommend measures to minimize differential settlement at bridge approaches.

METHODS

A literature review was conducted regarding issues involved in using, designing, and constructing approach slabs. Relevant articles and publications were selected using the Transport bibliographic database.

A survey of state DOTs that focused on issues concerning bridge approach slabs was developed and administered by the Virginia Transportation Research Council (VTRC) in consultation with VDOT's Structure & Bridge Division. The goal of the survey was to obtain feedback from state DOTs on the state of the practice concerning the use, design, and construction of bridge approach slabs. State DOT geotechnical, structural, and foundation engineers were surveyed in the 48 contiguous states. Appendix A shows the survey questionnaire, and Appendix B shows the individuals surveyed.

RESULTS

Literature Review

Although excessive settlement at a bridge approach is easy to spot, its causes are often complex. Figure 1 illustrates a typical approach slab configuration employed in bridge construction. The slab is usually supported on a backwall at one end and on the adjoining highway embankment at the other. Sometimes, a sleeper support slab is used, particularly in the case of portland cement concrete pavements, to equalize settlements beneath the roadway end. The bump that is often felt while driving over an approach slab reveals a differential settlement of an embankment relative to the superstructure. In most situations, the greatest concerns include deteriorating ride quality and impaired driver control of a vehicle. In extreme cases, the resulting impact traffic loading may adversely affect the service life of a structure.

With reference to Figure 1, it is evident that a finite amount of differential settlement is inevitable at virtually all bridge approaches. The bridge is typically constructed with deep foundations designed for a negligible abutment settlement. On the other hand, the adjoining approach embankment is built incrementally with numerous layers of fill material, which can settle appreciably if not properly placed and compacted. In addition, the underlying subsurface soils can undergo significant settlement because of consolidation caused by the weight exerted by the approach embankment. The consolidation component is often predominant in areas underlain by soft clays and silts. Other common contributions to fill settlement stem from embankment erosion and thermal bridge movements.

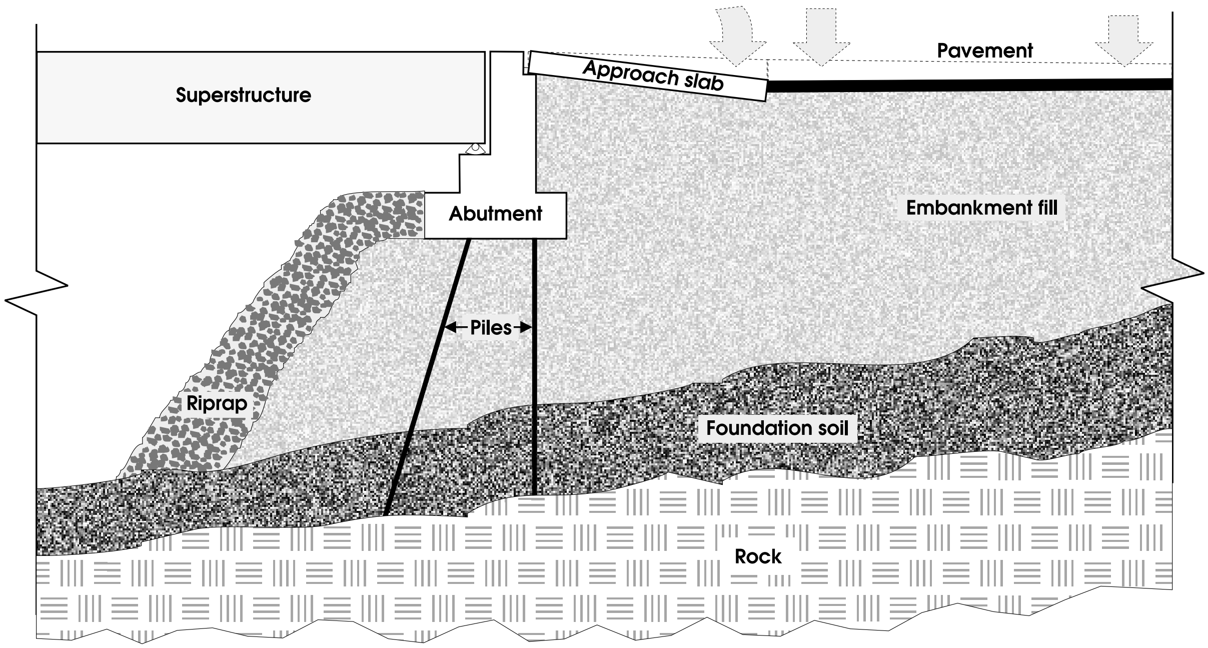

Figure 1. Bridge Approach Settlement

The presence of an approach slab has no effect on the magnitude of the differential settlement that will ultimately develop. The primary function of the approach slab is to provide a gradual transition, or a ramp, between the fixed superstructure and the settling embankment. Without an approach slab, the “bump” at the end of the bridge becomes much more abrupt. Thus, within practical limits, the length of an approach slab may be used as a variable to adjust the change in longitudinal gradient to an acceptable level. The question becomes “what is tolerable to the travelling public and what measures should be instituted to achieve and maintain that level of rider comfort in a cost-effective fashion?” In a recent study, Briaud et al. (1997) recommended a maximum allowable change in slope of 1/200, based on studies by Wahls (1990) and Stark et al. (1995). Long et al. (1988) also proposed a relative gradient of less than 1/200 to ensure rider comfort and a gradient of between 1/100 and 1/125 as a criterion for initiating remedial measures.

Several comprehensive studies of the performance of approach slabs have been sponsored over the years by various state DOTs. A study conducted at the California DOT (Caltrans) by Stewart (1985) identified the original ground subsidence and fill settlement as primary causes of approach maintenance problems. The resulting recommendations included using select fill material for a distance of 45 m (150 ft) from the bridge, waterproofing the approach embankment, and using approach slabs 9 m (30 ft) long. The proposed approach slab should be doweled into the backwall to ensure a watertight joint. In addition, the slab should be cantilevered over the wingwalls to minimize surface water infiltration.

A study conducted by the Washington State DOT (Kramer & Sajer, 1991) summarized findings from various state DOTs and recommended guidelines for the use and construction of approach slabs. While promoting the use of approach slabs in general, the researchers recommended that a design geotechnical engineer be responsible for assessing the need on a site-specific basis. The study also called for the use of select granular fill and stringent inspections of the placement and compaction of abutment backfill. The main causes of bridge approach distress were traced to consolidation of foundation soils, compression of embankment fill, and a localized soil settlement near the approach-abutment interface attributable to inadequate compaction.

Research conducted by Mahmood (1990) indicated that the type of abutment affects the magnitude of approach settlement. Spill-through or shelf abutments were associated with rougher approaches, as compared to the cantilever type. A lack of lateral confinement in the case of a spill-through abutment was found to contribute to increased soil erosion, resulting in accelerated approach embankment settlement. Traffic volume had no influence. The study recommended the use of various ground improvement techniques, including wick drains and surcharging, to mitigate the foundation soil settlement. The use of lightweight fill materials was also proposed as a means of reducing the vertical loading exerted on the foundation soil.

Chini et al. (1992) summarized critical items in the design and construction of bridge approaches. They recommended particular materials and construction techniques for approach embankments. These recommendations included removal and replacement of compressible foundation soils, dynamic compaction, surcharging, use of select borrow fill material, and minimum compaction requirements of 95% of the Standard Proctor (AASHTO T 99), coupled with increased construction inspection.

A recently completed NCHRP synthesis report on the settlement of approach slabs (Briaud et al., 1997) recommended more stringent requirements for fill material specifications and inspection practices. The study concluded that a close cooperation among geotechnical, structural, pavement, construction, and maintenance engineers correlates with lower reported incidences of excessive approach settlement.

Survey Results

Thirty-nine state DOTs responded to the survey (including partial responses), representing an 81% return rate. The results are grouped in the order of use, design, and construction practices. A complete set of raw survey responses is available from the author.

Advantages and Disadvantages of Using Approach Slabs

Eighty-one percent of respondents quoted a smooth ride as a primary advantage for the use of approach slabs (see Appendix C, Table C-1). (*Note:* All tables cited in this report may be found in Appendix C.) A reduced impact on the backwall was commonly given as a secondary advantage (41%), followed by enhanced drainage control (16%). Two states, Kentucky and Maryland, derive no clearly defined advantages from the use of approach slabs. Among primary disadvantages (see Table C-2), the initial high construction cost was quoted by 75% of respondents and maintenance problems with settling approach slabs were listed by 52%. Other disadvantages included difficulties with staged construction and increased construction time.

Extent of Usage

Table C-3 illustrates the percentage of bridges that include approach slabs in various states on interstate, primary, and secondary systems. Fifty percent of respondents use approach slabs on all interstate bridges. The majority of the remaining states indicated an interstate usage in excess of 80%. Geographically, the responses appear to be evenly distributed. The use of approach slabs on the primary highway system is also prevalent. Forty-two percent of respondents use them on all bridges, and virtually all others use them on over 50% of bridges. Usage on the secondary system varies significantly from state to state. Twenty-four percent of respondents, evenly distributed across the nation, indicated 100% utilization, and 21% use approach slabs on the majority of secondary bridges. Virginia's responses indicated usage on interstate and primary systems consistent with the national trend and relatively low usage on secondary roads.

Usage Criteria

The usage criteria employed by a DOT to determine whether to consider using an approach slab at the bridge project consist primarily of traffic volume (average daily traffic [ADT], average annual daily traffic [AADT], or design hourly volume [DHV]) and/or road functional classification. Survey respondents did not provide exact traffic volume thresholds for the use of approach slabs. In the case of conventional bridge abutments, 38% of respondents indicated specifying approach slabs at all times, regardless of the situation. One state listed an engineer's option as a main criterion, presumably based on a comprehensive geotechnical analysis. Other factors included pavement type and embankment height. In the case of integral bridge abutments, 60% of the respondents constructing this type of structure indicated that they use approach slabs at all times. The use of approach slabs in Virginia is governed by the volume of traffic and the functional classification of the road. Tables C-4 and C-5 show the typical usage criteria for conventional and integral bridges, respectively.

Special Inclusion/Exclusion Circumstances

With regard to special circumstances that would prompt them to include an approach slab in situations where one is normally excluded, 30% of responding DOTs do not typically consider any special cases. Twenty-four percent cited concerns about excessive settlement as the main factor in their decision.

Twenty-one percent of respondents indicated that a low estimated settlement would prompt them to exclude an approach slab, but 48% have no exclusion policy in place. Virginia provides for exclusions based on technical justification, as approved by the office of the state structure and bridge engineer. Tables C-6 and C-7 show individual responses.

Typical Dimensions of Approach Slabs

Fifty percent of respondents quoted a commonly used slab length as 6.1 m (20 ft). The shortest reported length was 3 m (10 ft), and the longest 12.2 m (40 ft). The reported thickness varied from 0.20 m (8 in) for a slab 4.6 m (15 ft) long to 0.43 m (17 in) for a slab 9.1 m (30 ft) long. Approach slabs with a typical length of 6.1 m (20 ft) were reported to have a thickness between 0.23 m (9 in) and 0.38 m (15 in), with an average of 0.30 m (12 in). Most respondents construct full-width (curb-to-curb) approach slabs. Virginia uses slabs 6.1 m (20 ft) long and 0.38 m (15 in) thick. Table C-8 shows all responses.

Slab Connections with Bridge Abutments

Fifty-seven percent of respondents indicated the use of doweled or tied connections, and 43% use no mechanical attachments for conventional bridges. Doweled connections are commonly used at integral bridges. Seventy-one percent of respondents with integral structures reported using mechanical connections at the approach slab/backwall interface. In Virginia, all approach slabs at conventional bridges are supported by a ledge poured monolithic with the backwall, whereas slabs at integral bridges are doweled. Table C-9 shows all responses.

Fill Specifications

A number of responding DOTs specify select fill material for bridge approach embankments. Forty-nine percent indicated the use of more stringent material specifications for the approach fill as contrasted with a regular highway embankment fill. A typical requirement is limiting the percentage of fine particles to reduce material plasticity and enhance drainage properties. The allowable percentage of material passing the 75-micron (No. 200) sieve varied from less than 4% to less than 20%. Virginia allows the use of a regular embankment fill at bridge approaches. Table C-10 summarizes the responses.

Construction Specifications

In the majority of states, including Virginia, the approach fill is constructed in 0.20-m (8-in) loose lifts of granular fill, compacted to 95% of the Standard Proctor value. Four states enforce strict 100% Standard Proctor compaction requirements. In many states, the range of allowable material moisture contents is not specified. Table C-11 summarizes the responses.

Drainage Provisions

Effective surface and subsurface drainage systems are essential in controlling soil erosion in highway embankments. Most states define specific requirements for drainage of bridge approach embankments. Typical provisions include plastic drainpipes; weep holes in the abutments; and the use of granular, free-draining fill. The use of geosynthetic materials, fabrics and geocomposite drainage panels, was reported by 24% of the respondents. Virginia design details call for the use of crusher-run aggregate and weep holes or pipe underdrains behind backwalls. VDOT also has a special provision allowing the use of geocomposite drains. The responses are shown in Table C-12.

Inspection

When asked if contractors are closely monitored during embankment construction, 73% of respondents felt confident that their quality control procedures relating to earthworks were satisfactory. The responses, which were for the most part uniformly distributed throughout the nation, are provided in Table C-13.

Construction Problems

Approximately 50% of respondents have had difficulty obtaining a specified degree of fill compaction in the proximity of bridge abutments. This is often cited as one of the main causes of approach slab settlement. Because of spatial limitations near the abutments, often imposed by the contractor's preferences, only small compaction equipment is normally used. Significantly, 32% of states that reported problems also claimed that they were satisfied with their quality assurance/quality control inspection procedures. The responses are provided in Table C-13.

Use of Recycled or Manufactured Materials

Approximately 27% of responding DOTs have experimented with the use of non-soil materials behind bridge abutments. Alternative construction materials typically include lightweight fills, such as shredded tires, to minimize the foundation soil settlement and geosynthetic reinforcement designed to increase the overall embankment stability and reduce erosion. In special design situations, VDOT has used Solite and Elastizell behind bridge abutments with good results. The responses are provided in Table C-13.

Order of Construction

Fifty-five percent of respondents stated that they typically build approach embankments before bridge abutments, and 18% responded that they were constructed either way. Usually, cantilever-type abutments are built prior to fill placement. The main advantage of placing approach embankments in advance of bridge abutments is that it allows a significant portion of the anticipated settlement to occur during construction, before the bridge is open to traffic. The responses are provided in Table C-14.

Is Approach Slab Settlement a Problem?

A clear majority, 55%, of respondents was convinced that approach slab settlement is a significant maintenance problem. Twenty-nine percent of respondents consider it a moderate problem. Sixteen percent do not view it as a problem. The responses are provided in Table C-15.

DISCUSSION

Frequency of Use

It is evident from the literature that excessive bridge approach settlements and associated maintenance issues have been studied and identified for some time. Over the years, a number of recommendations have been formulated and implemented with varying degrees of success. The survey results indicated that a majority of state DOTs still consider approach settlement to be a serious maintenance problem.

The frequency with which approach slabs are used varies drastically throughout the nation. At one extreme, 14 DOTs use them at all times (for conventional abutments), and at the other end of the spectrum, two DOTs (Kentucky and Maryland) practice a no-use policy, claiming that approach slabs serve only to move the bump from the end of the bridge to the end of the approach slab. Clearly, there is no national consensus as to the real benefits or drawbacks regarding the use of approach slabs. It is evident from the survey that there is no direct correlation between the extent of use of approach slabs and the resulting maintenance efforts. Other countries also have varying usage policies. For example, approach slabs are seldom used in Germany (Tophinke, 1997). Instead, stringent embankment material requirements and compaction control methods (100% Proctor) are specified, frequently in combination with ground improvement techniques. German guidelines do not promote reliance on approach slabs to mitigate differential settlement problems.

Influence of Traffic

VDOT policy stipulates that structural approach slabs are to be used in the initial construction of all interstate and arterial systems and all structures (except the secondary system) with a DHV over 200 and an ADT over 1250. In addition, approach slabs are mandated on secondary road bridges with a DHV over 400. Traffic counts apply to a design year. Thus, VDOT policy is based on a traffic volume and a road functional classification. The policy is essentially in line with the current national state of the practice, as the majority of state DOTs rely on these two variables in the decision-making process. VDOT also allows for exclusion of approach slabs when justified on technical merits by district structure and bridge engineers and approved by the Office of the State Structure and Bridge Engineer.

It appears that the ADT and DHV thresholds specified by VDOT for including approach slabs reflect relatively low traffic volumes. To put it in perspective, a recent study by Schrank and Lomax (1997) concluded that 15,000 vehicles per day per lane (vpdpl) for freeways is an estimate of the beginning of level of service D (LOS D) operation, signifying the onset of a significant traffic congestion. LOS runs from A to F, with A being "perfect" and F being "intolerable." Historically, typical VDOT designs are for LOS C during rush hour.

An assessment of traffic flow in freeway work zones, as provided in the *Highway Capacity Manual* (Transportation Research Board, 1994), indicates that typical open-lane capacities are in the range of 1,170 (one lane of three open) to 1,520 (three lanes of four open) vehicles per hour per lane (vphpl). Dixon et al. (1996) observed that the average speed in these work zones during the day can be maintained at 85 km/h (53 mph) for volumes below 1,100 vphpl.

If one accepts the premise that approach slabs are required on high-volume roads because of a greater likelihood of public complaints pertaining to bumps and limited maintenance accessibility when repairs are needed, then a closer look at ADT and DHV threshold values for mandatory use of approach slabs is warranted. The VDOT thresholds of 1,250 ADT and 200 DHV do not depend on the number of available traffic lanes. These thresholds are applied equally to eight-lane and two-lane roads, although the latter would typically be much more constraining from the standpoint of maintenance access.

Based on the existing studies, one can presume that the per-lane capacity in the work zone is at least 1,000 vehicles per hour. If one assumes that approach maintenance operations result in one-half of the initial number of lanes being available for traffic, then 500 vphpl would be a limiting factor. If one, somewhat arbitrarily, decides to accept only 50% of this value as a threshold that can be reasonably tolerated, then 250 vphpl could be used as a benchmark. This figure translates into 1,700 vpdpl (peak hourly traffic = 15% of daily traffic) according to the *Highway Capacity Manual* guidelines. It can be argued that the approach slab use considerations based on the per lane traffic flow (vpdpl and vphpl) would be more comprehensive than ADT and DHV thresholds because they reflect the number of available traffic lanes.

Influence of Subsurface Conditions and Compaction

It must be recognized that the factors contributing to the underlying settlement need to be addressed and resolved whether or not approach slabs are used. The use of approach slabs may result in reduced maintenance expenditures in situations involving a relatively small amount of differential settlement. In cases of substantial settlement, however, particularly at long-span integral bridges, the cost of repairing a failing approach slab may be significantly greater than the cost of placing recurrent overlays.

Consolidation of the original foundation soil beneath the approach embankment often constitutes the largest single component of the total settlement. Various techniques are available to minimize this problem, including removal and replacement, dynamic compaction, stone columns, deep soil mixing, wick drains, and surcharging. Another potentially available solution involves constructing embankments using a lightweight fill material such as expanded polystyrene to minimize the vertical stress exerted on the foundation soil and the resulting settlement (Frydenlund et al., 1997).

The implementation of a suitable ground improvement method, when considered necessary, needs to be done in the early design stages of a project. Federal Highway Administration guidelines for presenting data in the foundation investigation report explicitly call for settlement analysis of subsoils, including an estimate of the magnitude of the settlement, the time that will elapse before settlement, the required height of the surcharge, and recommendations on special ground improvement methods (Cheney & Chassie, 1993).

In Virginia, highly compressible soils are concentrated primarily in the eastern part of the state. Figure 2 shows the location of Virginia's five main physiographic provinces. With regard to subsoil settlement considerations, the most troublesome materials are distributed mainly in the Coastal Plain. They include deep, unconsolidated marine clay deposits of very high compressibility. Site conditions generally improve in the Piedmont, with the underlying igneous and metamorphic rocks. The surficial soil cover further decreases and competent rock becomes more abundant in the Blue Ridge, typically resulting in significantly less challenging settlement problems. Geotechnical conditions worsen again in the western part of the state. Extensive sedimentary rocks, including limestone and dolomite, underlie the Valley and Ridge and Appalachian Plateaus. The high solubility of the materials when in contact with the groundwater frequently results in karst conditions, causing numerous ground subsidence problems.

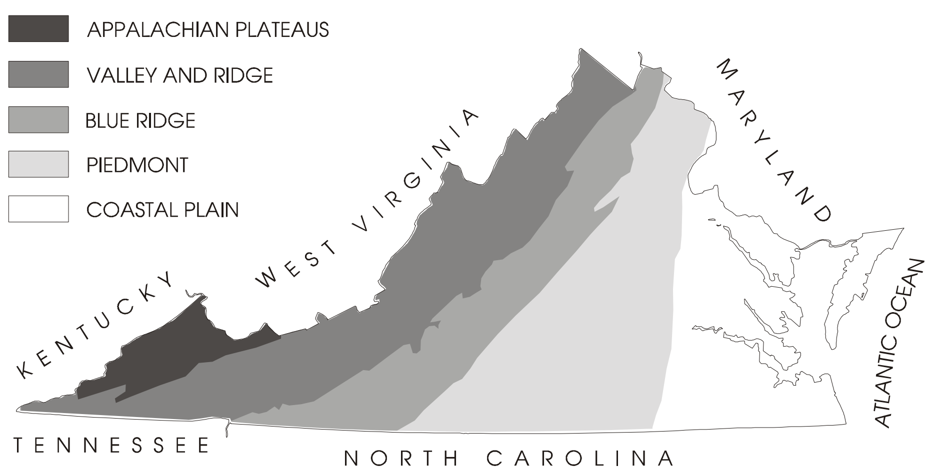

Figure 2. Physiographic Provinces of Virginia

The approach embankment settlement can be minimized by using select fill materials, installing effective drainage systems, and having strict compaction requirements. A rough estimate of the post-construction settlement can be made by assuming that the maximum and minimum void ratios for the granular fill are 0.8 and 0.5, respectively (Monahan, 1994). At a relative density of 95%, the corresponding fill settlement is approximately 1% of the embankment height. At a relative density of 98%, the fill settlement can be reduced to approximately one half of that amount. This indicates that in the case of a well-compacted granular fill, the settlement becomes a design issue at heights exceeding approximately 3 m (10 ft). Increasing fill compaction requirements from 95% to 98% of the Standard Proctor is likely to reduce the embankment settlement problems, but it would have no effect on the consolidation of the underlying foundation soil. In fact, survey results indicate that some agencies that specify 100% compaction still experience significant bridge approach settlements.

VDOT specifications do not call for the use of a select fill material at bridge approaches. This is in striking contrast with many other state DOTs. VDOT allows liberal use of conventional embankment fill, often containing a large amount of fines, at bridge abutments. In addition, the specifications allow material to be placed at a moisture content ranging within 20% of the optimum value, which sometimes results in a placement significantly wetter than optimum. Efforts are currently underway to tighten aspects of VDOT's specifications pertaining to earthworks at bridge approaches to reduce the potential for differential settlement. Changes being considered include specifying select fill material containing a low percentage of fines, increasing compaction test frequency, and reducing the range of allowable moisture contents during placement. The extent of select material being considered is a prism extending from the heel of the footing to a point 3 m (10 ft) away laterally and then rising at a slope of 1:1 toward the surface.

Survey results indicate that several highway agencies in the United States have adopted stricter compaction standards, with some calling for 100% relative compaction. At the same time, however, it is commonly recognized that fill compaction in the proximity of the backwall requires special attention to avoid excessive lateral pressures. This concern, coupled with a relatively confined compaction zone behind the abutment, necessitates the use of light, portable compactors. Frequently, a localized section of poorly compacted material is formed, contributing to the subsequent approach settlement. One possible solution is the use of flowable fill, also referred to as controlled low-strength material. The ongoing NCHRP Project 24-12 (Controlled Low-Strength Material for Backfill, Utility Bedding, Void Fill, and Bridge Approaches) is structured to provide more practical guidance in this area.

Settlement and Design Issues

Currently, VDOT has no established roughness criteria for initiating maintenance operations on bridges and bridge approaches. In the absence of adopted standards, a change in the approach gradient of 1/125 may be regarded as a criterion for initiating remedial measures and a gradient of 1/200 may be considered as satisfactory for rider comfort (Long et al., 1997).

Applying these limits, the required design length of an approach slab (L) can be estimated as (Briaud et al., 1997):

$$L >= 200\ (sf - sa)$$

where sf is the estimated total fill settlement at the end of the approach slab, and sa is the estimated settlement of the bridge abutment.

If the bridge abutment is constructed on deep foundations, then the value of sa can be assumed to be zero. Based on survey responses, the design slab length varies between 3 m (approximately 10 ft) and 12 m (approximately 40 ft), corresponding to acceptable differential settlements ranging between 15 mm (0.6 in) and 60 mm (2.4 in).

Additional anticipated movement can be accommodated by a technique of roadway pre-cambering (Tadros & Benak, 1989), thus accounting for the frequently inevitable post-construction settlement. If one assumes that the approach pavement can be pre-cambered upward to a 1/125 change in gradient corresponding to the maintenance limit, the range of rider-acceptable differential settlements would be effectively extended to 155 mm (6.1 in).

On low-volume roads, resurfacing a settling bridge approach pavement (in one or several operations over time) may be more cost-effective than constructing an approach slab. An additional maintenance effort is likely to be required only in the first 2 or 3 years following construction. Resurfacing may be considered a practical solution on low-volume roads with a total anticipated differential settlement not exceeding 100 to 150 mm (4 to 6 in) if it can be proven to reduce the total lifetime cost of the project.

Other potentially valid considerations for deleting an approach slab include the presence of an existing, already consolidated fill (on bridge replacement projects) and low embankments overlying bedrock, where any subsequent settlement is likely to be negligible. At the other extreme, in situations involving a very large predicted post-construction settlement, approach slabs may be eliminated since no real benefit will be gained from their use. This is a recommended policy at the Washington State DOT (Jenkins, 1996) when preventive measures aimed at minimizing differential settlement are impractical to implement and repaving becomes the most cost-effective option. However, when approach slabs are not used, the abutments must be designed to accommodate additional traffic loading, as outlined in the AASHTO *Road and Bridge Specifications.*

Frequent resurfacing of bridge approaches would not be regarded as a practical solution on high-volume roads where extensive traffic control measures, safety considerations, and potential traffic congestion do not favor maintenance activities. The use of approach slabs in these situations would be preferred since they would “buy” more time before the repairs are necessary or even eliminate remedial actions if settlements of a small magnitude occur. The use of approach slabs in these situations is likely to eliminate several iterations of pavement buildup.

When an approach slab settles excessively, the available repair options typically consist of either mudjacking or overlaying with additional pavement. On portland cement concrete pavements and at integral bridges, possible repairs include placing a thin-bonded overlay and jacking up or replacing settling approach slabs. A significantly less expensive option of resurfacing is available in the case of asphalt pavements. VDOT has been constructing approach slabs buried 50 to 100 mm (2 to 4 in) below the final grade to permit planing and overlay with asphalt pavement without creating feathering problems at the bridge end. This design was further refined by the Massachusetts Highway Department, as shown in Figure 3. The slab is placed at approximately 610 mm (24 in) below the deck elevation, supporting bituminous pavement and the underlying base material. A positive drainage of subsurface water away from the backwall is achieved through a longitudinal slope. It appears that this design may be more effective in situations involving large differential settlements at bridge approaches. Figure 4

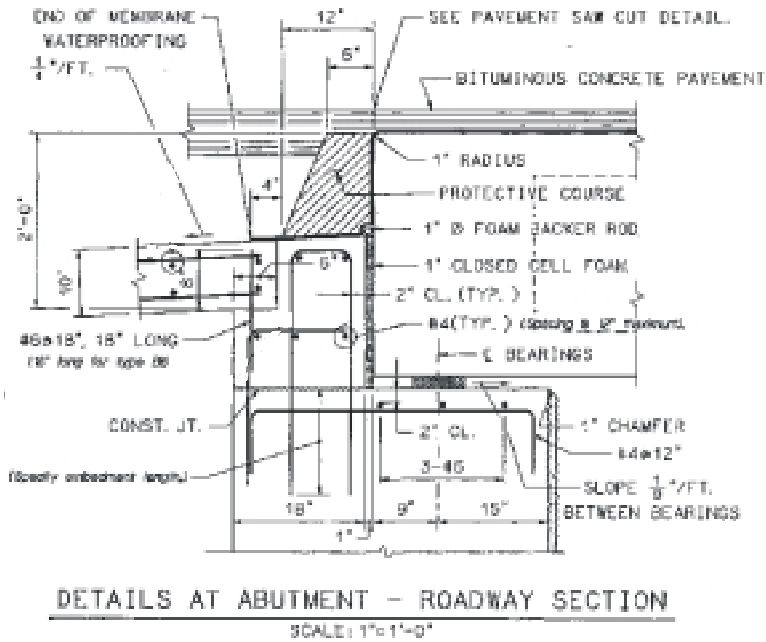

Figure 3. Massachusetts Highway Department Approach Slab Detail (Drawing No. 4.4.12, dated 4/1994)

Figure 4. Approach Slab Distress Attributable to Foundation Soil Settlement (Rte. 10 westbound lane over the Appomattox River)

shows an extreme example of a failure of the VDOT design, with a layer of asphalt pavement breaking around the periphery of the approach slab. The approach distress was caused by the excessive consolidation of the underlying soft soils. When breaks in the pavement developed at the edge of the approach slab, surface water infiltration and erosion compounded this maintenance problem.

The “buried” approach slab is obviously not suitable at integral bridges unless special measures are taken to allow for unrestrained lateral movement of the superstructure. VDOT, like most other DOTs, specifies a doweled slab connection at the integral backwall. Excessive settlement of approach slabs at integral bridges is particularly serious because of the possibility of backwall damage. The potential for settlement is particularly acute because of repetitive lateral, thermally induced movement of the superstructure and the resulting compression of the adjacent fill (Hoppe & Gomez, 1997). The exclusion of approach slabs at integral bridges can result in overly frequent pavement maintenance operations. This issue is being addressed by the Virginia Transportation Research Council through a field study aimed at selecting compatible backfill materials.

VDOT approach slabs are typically 6.1 m (20 ft) long and of pavement width unless the shoulder has a full-depth pavement, in which case the slab width is extended across the shoulder. The majority of state DOTs responding to the survey indicated that they used full-width slabs, mainly because of the improved channeling of surface runoff that reduces embankment soil erosion contributing to differential settlement.

VDOT’s Staunton District has adopted a novel design detail to combat erosion at the backwall/pavement interface (see Figure 5). The objective is to break the flow path of surface water particles by cantilevering the bridge deck beyond the backwall and providing a drip bead at the underside of the extending portion. The overhang is typically 305 mm (12 in) deep and cantilevers approximately 100 mm (4 in) beyond the backwall. It is based on a modified VDOT standard from the 1950s.

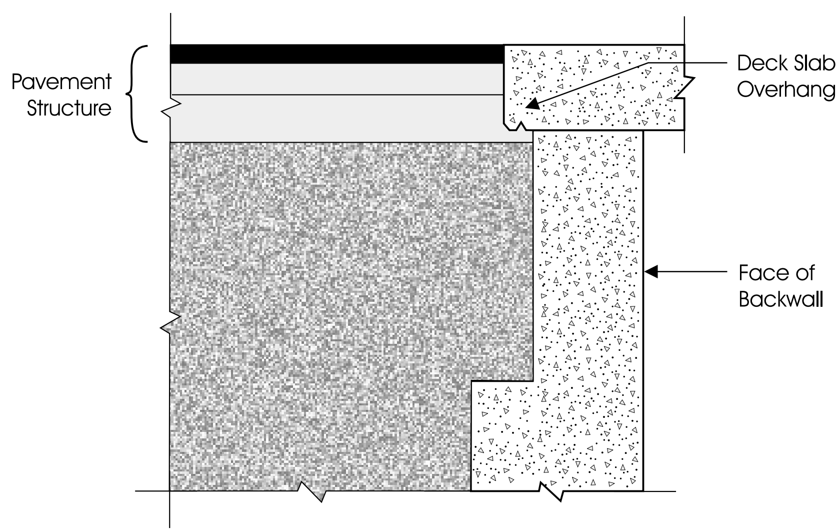

Figure 5. Erosion Control Design Detail for Bridges Without Approach Slabs (VDOT’s Staunton District)

CONCLUSIONS

- Virtually every state DOT employs a unique set of criteria governing the use, design, and construction of bridge approach slabs. There are no commonly accepted standards for evaluating the effectiveness of approach slabs and no unified policy for selecting them. A common trend is to use approach slabs on all high-volume roads, typically on the interstate and primary systems. Beyond that, usage guidelines, design methodology, material specifications, and construction techniques differ greatly from state to state.

- The traffic volume VDOT currently uses as a criterion for selecting approach slabs appears to be too conservative.

- Full-width approach slabs are used by the majority of state DOTs. The primary advantage of this design is reduced erosion of the approach fill, which results in less differential settlement.

- Placing approach slabs below the road surface facilitates resurfacing operations. An additional design consideration should involve providing drainage between the top of the approach slab and the surface of the road.

- Some differential settlement at bridge approaches is unavoidable because of differing foundations beneath the bridge and the roadway. Pre-cambering may be employed to compensate for this phenomenon.

- The majority of state DOTs consider bridge approach settlement a serious and persistent maintenance problem.

- Differential settlement and the resulting bump at the end of the bridge should be viewed as problems that require engineering analysis on a site-specific basis to derive a cost-effective solution. Approach fills should be considered structural elements, directly affecting performance of the adjoining bridge. The use of bridge approach slabs without due regard for ground improvement and embankment design and construction issues addresses only the symptoms and not the cause of the underlying problem.

RECOMMENDATIONS

The following recommendations are directed to VDOT’s Bridge, Materials, and Location & Design divisions:

1. *Adopt new traffic volume thresholds, higher than the currently stipulated ADT and DHV values, for considering the use of approach slabs.* A new limit of 1,700 vehicles per day per lane (vpdpl) and 250 vehicles per hour per lane (vphpl), reflecting the available traffic capacity for maintenance access, would seem

appropriate. VDOT should monitor and analyze the impact of adopting new threshold values with follow-up studies.

2. *Require the use of bridge approach slabs in the initial construction of all structures on Virginia's highways with design traffic volumes exceeding both thresholds.* The district bridge engineer should have the option of using approach slabs in the remaining cases. All requests for design exceptions should be directed to the Office of the State Structure and Bridge Engineer for review. For design exceptions involving omitting an approach slab, the impact on the road maintenance schedule should be communicated to the resident engineer.

3. *When approach slabs are omitted, ensure that the abutment design computations account for the additional live load attributable to traffic in accordance with AASHTO specifications.*

4. *Construct bridge approach slabs to the full width (curb to curb) of roadway to minimize settlement caused by surface water infiltration and subsequent embankment erosion.*

5. *Ensure that the length of approach slabs are compatible with the expected settlement.* Longer approach slabs should be considered in cases involving very soft foundation soils and/or high embankments to provide a more gradual transition in areas of potentially high differential settlement.

6. *Bury approach slabs constructed at asphalt roadways and at non-integral bridges below the current 50 to 100 mm (2 to 4 in) design depth to facilitate resurfacing operations and allow drainage between the pavement and the underlying approach slab.* A proposed design detail, with the underside of the approach slab placed at 700 mm (28 in) below the surface and sloping away from the backwall, is shown in Figure 6. This detail allows placement of the full pavement section on top of the approach slab and provides for drainage of subsurface water away from the backwall.

7. *In all geotechnical foundation reports for all bridge projects, include a comprehensive settlement analysis of subsoils and provide recommendations on ground improvement pertaining to approach embankment construction.* Bridge approach settlement should be treated as a separate design issue, accounting for specific subsurface soil conditions, traffic volume, type of structure, and maintenance accessibility. The resources currently allocated to carry out these tasks should be reviewed and augmented if necessary to better serve the needs of VDOT and the travelling public.

8. *Where applicable, carry out ground improvement procedures in the early stages of a project to minimize any residual long-term embankment settlement.* One of the most effective means of mitigating long-term settlement problems is surcharging, which requires advance planning and coordination to ensure that most of the anticipated settlement occurs during construction.

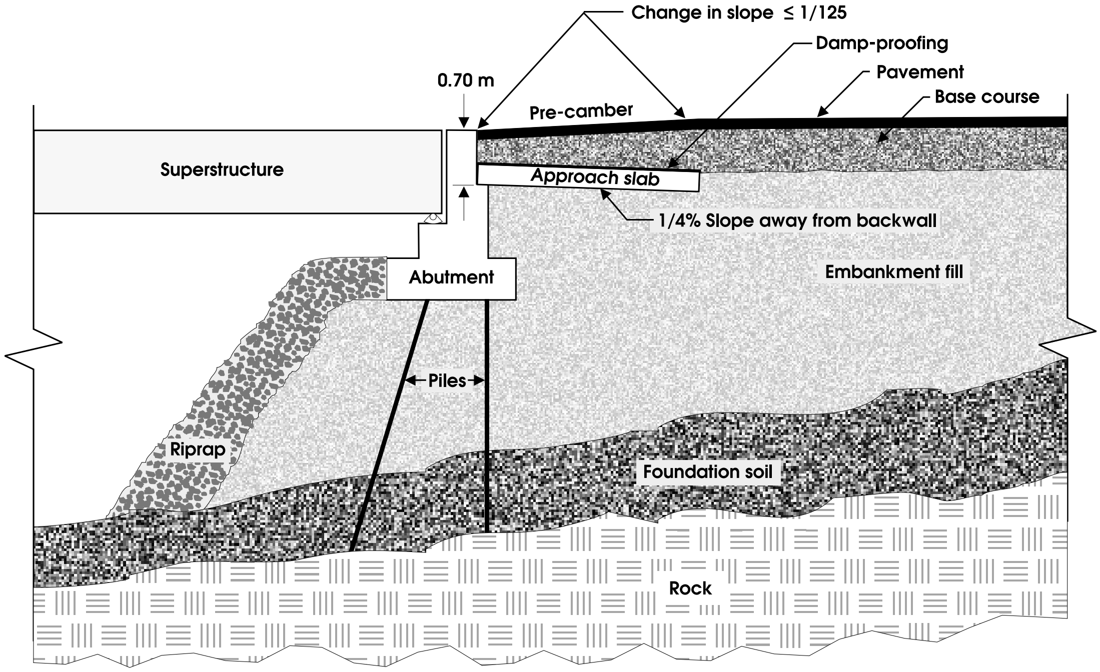

Figure 6. Proposed Approach Slab Details for Non-Integral Bridges

9. *Adopt fill material specifications designed to minimize embankment compression settlement for bridge approach construction.*

10. *Where practical, implement pre-cambering of bridge approaches at up to a 1/125 longitudinal gradient for a minimum distance from the backwall equal to the length of the approach slab to accommodate the differential settlement that will inevitably occur between a structure constructed on deep foundations and adjoining earthworks.* It is proposed that this concept be implemented gradually over 2 or 3 years to allow for monitoring and performance assessment.

ACKNOWLEDGMENTS

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APPENDIX A

BRIDGE APPROACH SLAB SURVEY

The purpose of this survey is to evaluate current VDOT policy on the use of bridge approach slabs. Responses from various state DOTs will be analyzed. We will provide you with a copy of the final report. Your participation is greatly appreciated.

AGENCY:

NAME: TITLE:

1. Approximately what percentage of your bridges include approach slabs? Please list by Interstate, Primary, and Secondary system.

2. What are your criteria for the use of approach slabs (i.e. ADT, road functional classification, fill height) on bridges with:

   a) conventional abutments?

   b) integral abutments?

3. What special circumstances would you consider in your decision to:

   a) include an approach slab on a bridge not meeting the above criteria?

   b) exclude an approach slab on a bridge meeting the above criteria?

4. What benefits and disadvantages do you derive from the use of approach slabs?

5. What are the typical dimensions of your approach slabs? If possible, please send us a copy of your standard.

6. How are your approach slabs connected with bridge abutments? Please identify both conventional and integral abutments.

7. What are your material specifications for a fill adjoining a bridge abutment and are they different from those pertaining to regular embankments?

8. What are your construction specifications on lift thickness, percent compaction, and type of compaction equipment for a fill placed adjacent to bridge abutments?

9. Are contractors closely monitored by your inspectors during backfilling and compaction at abutments?

10. Do you often experience difficulties in obtaining a specified degree of fill compaction at abutments?

11. Has your agency ever used or considered using recycled or manufactured materials for backfilling at abutments? If so, please provide details.

12. What are the drainage provisions at your abutments?

13. Do you typically build approach embankments before or after abutment construction?

14. Is approach slab settlement a significant maintenance problem for your agency and, if so, what steps has your agency taken to mitigate it?

15. Remarks:

Thank you for taking the time to respond to this survey. Please fax your responses to:

Virginia Transportation Research Council
Att.: Edward Hoppe
Fax: (804) 293-1990

APPENDIX B

SURVEY CONTACTS

STATE	CONTACT NAME	PHONE	FAX
AL	Mitchell Kilpatrick	334-242-6272	334-832-9084
AR	John Annable	501-569-2496	501-569-2368
AZ	Shafi Hasan	602-255-8478	602-407-3056
CA	Minh Ha	916-227-8682	916-227-8379
CO	J. B. Gilmore	303-757-9275	303-757-9242
CT	Leo Fontaine	203-594-3180	203-594-3175
DE	Chao Hu	302-739-4355	302-739-2217
FL	Joe Bhuvasorakul	904-488-6461	904-488-6352
GA	Tom Scruggs	404-363-7546	404-363-7684
ID	Tri Buu	208-334-8448	208-334-8595
IL	Emile Samara Robert Dawe	217-782-7773	217-782-7960
IN	Steve Morris	317-232-5280	317-356-9351
IO	George Sisson	515-239-1461	515-239-1891
KS	Kenneth Hurst	913-296-3008	913-296-6946
KY	Henry Mathis Richard Sutherland	502-564-3670	502-564-4839
LA	J. B. Esnard	504-379-1822	504-379-1351
ME	Gerald Boucher	207-941-4536	504-287-6737
MD	John Logan	410-545-8320	410-333-3139
MA	Nabil Howrani	617-973-8832	617-973-7554
MI	Mr. Kulkarni	517-322-1633	517-322-5664
MN	Gary Peterson	612-582-1101	612-582-1110
MS	Harry James	601-944-9342	601-944-9300
MO	Ron Temme	314-751-3801	314-751-6555
MT	William Fullerton	406-444-6280	406-444-6204
NE	Bruce Thill	402-479-3930	402-479-4325
NH	Mark Whitemore Fred Prior Byron Peck	603-271-2731	603-271-1649
NJ	Jack Mansfield	609-530-3755	609-530-3689
NM	Martin Gavurnik	505-827-5432	505-827-5345
NV	Bill Crawford	702-687-5526	702-687-3102
NY	Phillip Walton	518-457-4712	518-457-8080
NC	Bill Moore	919-250-4088	919-250-4237
ND	Steven Miller	701-328-2592	701-328-4545
OH	Muhammad Riaz	614-466-2399	614-752-4824
OK	Veldo Goins	405-521-2554	405-522-0134
OR	Jerry Bellin	503-986-3372	503-986-3407
PA	George DiCarlantonio	717-783-7456	717-783-8217
RI	Jeff Dephillipo	401-277-2525 ext. 4137	401-277-6038
SC	Randy Cannon	803-737-1420	803-737-1881
SD	Kevin Goeden Vernon Bump	605-773-3285 605-773-3401	605-773-6608
TN	William Trolinger	615-350-4130	615-782-7960
TX	George Odom	512-416-2557	512-416-2286
UT	Ed Keane	801-965-4320	801-965-4796

VT	Warren Tripp	802-828-2561	802-828-2792
WA	Chuck Ruth	206-705-7209	206-705-6814
WI	Stan Woods	608-266-8348	608-246-4669
WV	Glen Sherman	304-558-3043	304-558-0253
WY	Patrick Collins	307-777-4205	307-777-3994
VA1	Thomas Wong	703-934-0790	703-383-2470
VA2	James Tavenner	804-524-6138	804-524-6273
VA3	Vince Roney	757-925-2547	757-925-1526
VA4	Garry Lovins	540-669-9941	540-669-0826
VA5	Larry Hedgepeth	804-786-6369	804-786-2988

APPENDIX C

TABLES

Table C-1. Advantages of Using Approach Slabs

State	Smooth Ride	Reduced Impact	Control Drainage	Uniform Settlement	Lower Maint. Cost	Seismic Stability	Minimum Deviation at Joints	None
AL	X	X						
AZ	X	X						
CA	X							
CT	X							
DE	X							
FL	X							
GA	X							
ID		X		X				
IL			X	X				
IN	X			X				
IO	X	X					X	
KS	X	X	X					
KY								X
LA		X						
ME	X	X		X				
MD								X
MA	X							
MN	X	X						
MS	X							
MO	X					X		
MT	X	X						
NE	X		X	X	X			
NH				X				
NJ	X	X						
NM	X							
NY	X							
ND	X				X			
OH	X							
OK	X							
OR	X		X	X		X		
SD	X	X	X					
TX	X							
VT	X	X						
VA	X	X		X				
WA	X					X		
WI	X	X			X			
WY		X	X	X				

Table C-2. Disadvantages of Using Approach Slabs

State	Higher Initial Cost	Maint.	Erosion	Bending Stress at Backwall	Problems w/Staged Construction	Joints	Rough Surface	Increased Construction Time
CA	X							
DE	X	X	X					
GA		X	X					
IL	X							
IN	X							
IO	X	X						
KS	X	X						
KY	X	X						
LA				X				
ME	X							
MN		X						
MO	X							
MT		X	X			X		
NE	X	X						
NJ		X						
ND	X							
OK	X							X
OR	X						X	X
SD	X	X						
VA		X	X					
WA	X				X			
WI	X	X						
WY	X							

Table C-3. Current Use of Approach Slabs (%)

State	Interstate System	Primary System	Secondary System
AL	100	100	20
AZ	100	100	80
CT	< 50	< 50	< 50
DE	90	65	20
FL	100	100	100
GA	100	100	100
ID	“small”	“small”	“very small”
IL	100	100	90
IN	100	100	100
IA	100	75	10
KS	90	50	20
KY	35	35	35
LA	100	100	100
ME	>50	>50	>50
MD	<1	<2	0
MA	100	100	100
MN	90	69	8
MO	100	100	10
MS	100	100	85
MT	<5	<5	<1
NE	100	100	100
NV	100	100	100
NH	95	30	7
NM	80	80	80
NY	100	100	100
ND	75	60	0
OH	100	95	75
OK	100	>90	0
OR	100	100	100
SC	100	100	30
SD	95	90	5
VT	100	100	100
VA	98	75	< 4
WA	75	50	25
WI	100	100	25
WY	90	75	50

Table C-4. Criteria for Use of Approach Slabs with Conventional Abutments

State	Use on All Bridges	ADT, AADT, DHV	Pavement Type	Settlement Expected	Road Functional Classification	Embankment Height	Engineer's Option	Not Used
AL		X			X			
AZ	X							
CA			X		X			
CT			X	X				
DE		X		X	X	X		
FL	X							
GA	X							
ID			X					
IL					X			
IN	X							
IA		X	X	X	X			
KS		X	X					
KY								X
MA	X							
MD								X
ME		X		X	X	X		
MN					X			
MS	X							
MO	X							
MT		X	X					
NE	X							
NH	X							
NJ		X			X			
NM	X							
NV	X							
NY	X							
ND					X			
OH				X				
OK					X			
OR		X						
SC		X				X		
SD					X			
TX							X	
VT	X							
VA		X			X			
WA				X				
WI					X			
WY	X							

Table C-5. Criteria for Use of Approach Slabs with Integral Abutments

State	Use on All Bridges	ADT, AADT, DHV	Pavement Type	Settlement Expected	Road Functional Classification	Embankment Height	Engineer's Option	Not Used
AL								X
AZ	X							
CO	X							
CT			X	X				
DE								X
FL								X
GA	X							
ID	X							
IL	X							
IN	X							
IA		X	X	X	X			
KS		X	X	X				
KY	X							
MA	X							
MD								X
ME		X		X		X		
MN					X			
MS								X
MO	X							
MT		X	X					
NE	X							
NH	X							
NJ								X
NM	X							
NV	X							
NY	X							
ND					X			
OK	X							
OR		X						
SC		X				X		
SD					X			
TX								X
VT	X							
VA	X							
WA				X				
WI					X			
WY	X							

Table C-6. Special Inclusion Circumstances

State	Skew	Expected Settlement	Road Class	Engineer's Option	Traffic Volume	Span Length	Pavement Type	Seismic Stability	All Bridges	None
AL				X						
AZ										X
CT										X
FL									X	
GA									X	
ID	X	X								
IL										X
IN									X	
IO		X								
KS				X						
KY			X		X	X				
MA										X
ME		X								
MN		X			X					
MS										X
MO										X
MT		X			X					
NE									X	
NH									X	
NJ		X								
NY									X	
ND										X
OH									X	
OK					X					
OR		X								
SC										X
SD			X							
TX										X
VT					X		X			
VA		X	X	X	X					
WA								X		
WI				X						
WY										X

Table C-7. Special Exclusion Circumstances

State	No Settle. Expected	Excessive Settle. Expected	Engineer's Option	Traffic Volume	Existing Embank.	Span Length	Pvmt. Type	Rocky Terrain	Retro-fit	None
AL				X						
AZ										X
CT										X
DE						X				
FL										X
GA										X
ID										X
IL										X
IN										X
IO	X			X						
KS										X
KY	X									
ME	X									
MA										X
MS										X
MT										X
NE	X									
NV									X	
NH										X
NJ	X							X		
NY										X
ND				X						
OH					X					
OK										X
OR	X									
SC	X			X						
SD							X			
TX										X
VT				X			X			
VA				X						
WA		X								
WI			X							
WY										X

Table C-8. Typical Approach Slab Dimensions

State	Length, m (ft)	Thickness, mm (in)	Width	Miscellaneous
AL	6.1 (20)	230 (9)	Pavement	
AZ	4.6 (15)			
CA	3.0-9.1 (10-30)	305 (12)	Curb-Curb	
DE	5.5-9.1 (18-30)			
FL	6.1 (20)	305 (12)	Curb-Curb	
GA	6.1-9.1 (20-30)	254 (10)	Curb-Curb	
ID	6.1 (20)	305 (12)		Length varies with skew angle
IL	9.1 (30)	380 (15)	Curb-Curb	
IN	6.2 (20.5)			Length varies with skew angle
IO	6.1 (20)	254-305 (10-12)	Pavement	Length varies with skew angle
KS	4.0 (13)	254 (10)	Curb-Curb	
KY	7.6 (25)		Curb-Curb	
LA	12.2 (40)	405 (16)	Curb-Curb	Length varies with skew angle
ME	4.6 (15)	203 (8)	Curb-Curb	
MA		254 (10)		Slab is sloped longitudinally
MN	6.1 (20)	305 (12)	Pavement	T-beams
MS	6.1 (20)		Curb-Curb	
MO	7.6 (25)	305 (12)		Timber header at sleeper slab
NV	7.3 (24)	305 (12)	Curb-Curb	
NH	6.1 (20)	380 (15)		
NJ	7.6 (25)	457 (18)		Used with transition slab 9.1 m x 230-457 mm (30 ft x 9-18 in)
NM	4.6 (15)		Curb-Curb	
NY	3.0-7.6 (10-25)	305 (12)	Curb-Curb	Sleeper slab, length varies with abutment type
ND	6.1 (20)	356 (14)	Curb-Curb	
OH	4.6-9.1 (15-30)	305-432 (12-17)		Length varies with embankment and skew angle
OK	9.1 (30)	330 (13)	Curb-Curb	
OR	6.1-9.1 (20-30)	305-356 (12-14)	Curb-Curb	Length varies with fill height and skew angle
SC	6.1 (20)			
SD	6.1 (20)	230 (9)		
TX	6.1 (20)	254 (10)		
VT	6.1 (20)			
VA	6.1-8.5 (20-28)	380 (15)	Pavement	Length varies with skew angle
WA	7.6 (25)	330 (13)	Pavement	Length varies with skew angle
WI	6.2 (20.5)	305 (12)		
WY	7.6 (25)	330 (13)	Curb-Curb	Sleeper slab 1.7 m x 254 mm (5.5 ft x 10 in)

Table C-9. Slab to Backwall Connection

State	Conventional Bridges		Integral Bridges		Integral Abutments Not Used
	Doweled or Tied	No Connection	Doweled or Tied	No Connection	
AL	X				X
AZ		X			
CA	X		X		
CT		X			
DE		X			X
FL	X				X
GA		X			
ID	X		X		
IL	X		X		
IN		X	X		
IA	X			X	
KS	X		X		
KY		X			
LA	X				
ME		X	X		
MD					X
MA	X			X	
MN		X	X		
MO	X				
MS		X			X
MT		X			
NV	X			X	
NH	X				
NJ		X			X
NM	X				
NY		X			
ND		X		X	
OH	X				
OK	X		X		
OR	X		X		
SC	X				
SD		X		X	
TX	X				X
VT	X				
VA		X	X		
WA	X		X		
WI		X			
WY	X		X		

Table C-10. Embankment Material Specifications

State	Same/Different from Regular Embankment	% Passing 75 µm (No. 200) Sieve	Miscellaneous
AL	Same		A-1 to A-7
AZ	Different		
CA		<4	Compacted pervious material
CT	Different	<5	Pervious material
DE	Different		Borrow type C
FL	Same		A-1,A-2-4 through A-2-7,A-4,A-5,A-6,A-7 (LL<50)
GA	Same		GA Class I, II or III
ID			A yielding material
IL	Different		Porous, granular
IN	Different	<8	
IO	Different		Granular; can use Geogrid
KS			Can use granular, flowable or light weight
KY		<10	Granular
LA			Granular
ME	Different	<20	Granular borrow
MA	Different	<10	Gravel Borrow" type B, M1.03.0
MI	Different*	<7	*Only top 0.9 m (3 ft) are different (granular materials Class II)
MN		<10	Fairly clean granular
MS	Different		Sandy or loamy, non-plastic
MO			Approved material
MT	Different	<4	Pervious
NE			Granular
NV	Different		Granular
NH	Same	<12	
NJ	Different	<8	Porous fill (Soil Aggregate I-9)
NM	Same		
NY		<15	<30% Magnesium Sulfate loss
ND	Different		Graded mix of gravel and sand
OH	Same		Can use granular material
OK	Different*		*Granular just next to backwall
OR	Different		Better materials
SC	Same		
SD	Varies*		*Different for integral; same for conventional
TX	Same		
VT	Same		Granular
VA	Same		Porous backfill
WA			Gravel borrow
WI	Different	<15	Granular
WY	Different		Fabric reinforced

Table C-11. Lift Thickness and Percent Compaction Requirements

State	Lift Thickness, mm (in)	% Compaction	Miscellaneous
AL	203 (8)	95	
AZ	203 (8)	100	
CA	203 (8)	95*	* For top 0.76 m (2.5 ft)
CT	152 (6)*	100	*Compacted lift indicated
DE	203 (8)	95	
FL	203 (8)	100	
GA		100	
ID	203 (8)	95	
IL	203 (8)	95*	*For top, remainder varies with embankment height
IN	203 (8)	95	
IO	203 (8)	None	One roller pass per inch thickness
KS	203 (8)	90	
KY	152 (6)*	95	*Compacted lift indicated; Moisture = +2% or -4% of optimum
LA	305 (12)	95	
ME	203 (8)		At or near optimum moisture
MD	152 (6)	97*	*For top 0.30 m (1 ft), remainder is 92%
MA	152 (6)	95	
MI	230 (9)	95	
MN	203 (8)	95	
MS	203 (8)		
MO	203 (8)	95	
MT	152 (6)	95	At or near optimum moisture
NE		95	
NV		95	
NH	305 (12)	98	
NJ	305 (12)	95	
NY	152 (6)*	95	*Compacted lift indicated
ND	152 (6)		
OH	152 (6)		
OK	152 (6)	95	
OR	203 (8)	95*	*For top 0.91 m (3 ft), remainder is 90%
SC	203 (8)	95	
SD	203-305 (8-12)*	97	*0.20 m (8 in) for embankments, 0.30 m (12 in) for bridge end backfill
TX	305 (12)	None	
VT	203 (8)	90	
VA	203 (8)	95	+ or –20% of optimum moisture
WA	102 (4)*	95	*Top 0.61 m (2 ft), remainder is 0.20 m (8 in)
WI	203 (8)	95*	*Top 1.82 m (6 ft and within 60 m (200’), remainder is 90%
WY	305 (12)		Use reinforced geotextile layers

Table C-12. Drainage Provisions

State	Plastic Pipe	Weep holes	Joint Seal	Granular Fill	Miscellaneous
AL					Open joint on bridge side of abutment
AZ					Geocomposite
CA	X				Filter fabric; geocomposite
CT		X*			*or 152 mm (6 in) underdrain
DE	X	X			
FL			X		Divert water from abutment
GA			X*		*or curb and gutter
ID				X	
IL	X		X		76 x 127 mm (3 x 5 in) curb; can use inlet box
IN	X			X	
IO	X		X		Subdrain at bottom of fill
KS	X		X		Filter fabric and strip drain
KY	X			X	
LA					Wedge of drainable material
ME		X			French drains at abutment and wingwalls
MA					Box culvert, curb, waterproofing
MI	X			X	Underdrain at top of footing
MN				X	Curb and gutter, underdrain at top of footing
MS					No special provisions
MO	X*				*or steel pipe; geotextile fabric
MT	X				Geocomposite
NE					Drainage matting; rock riprap
NH		X*		X	*102 mm (4 in) in diameter
NJ	X*	X		X	*or steel pipe
NM					No special provisions
NY				X	Drainage board
ND	X*				*if soil heave is expected; trench at bottom of backfill.
OH	X			X*	*0.61 m (2 in) thick; underdrain
OK					Underdrain at back of bridge seat
OR			X		End panels; catch basin
SC		X			Geotextile fabric and drains
SD	X				Drainage fabric and waterproofing
TX					No special provisions
VT					No special provisions
VA	X	X		X	
WA					Catch basins and deck grading
WI				X	Underdrains if impervious soil
WY	X				Drainage and filtration geotextile

Table C-13. Construction Issues

State	Contractors Closely Monitored?	Difficulties Obtaining Specified Degree of Compaction at Abutments?	Recycled or Manufactured Materials Ever Used for Backfilling Abutments?
AL	X	X	
AZ	X		
CA	X		
CT	X	X	X
DE	X		
FL	X		
GA	X	X	
ID	X		
IN	X		
IA	X		
KS		X	X
KY	X	X	X
LA	X	X	X
MA		X	
MD			
ME	X		X
MI	X		X
MS		X	
MO	X		
MT		X	
NE		X	
NH	X	X	
NJ	X	X	
NM	X		
NY	X		
OH		X	
OK		X	
OR	X	X	X
SC	X		X
SD	X	X	X
TX	X	X	
VT	X		
VA	X	X	X
WA	X		X
WI	X		
WY	X	X	

Table C-14. Do You Typically Build Approach Embankments Before or After Abutment Construction?

State	Before	After
AL	X	
AZ		X
CA	X	
CT	X	
DE		X
FL		X
GA	X	X
ID	X	
IN	X	
IA	X	
IL	X	
KS	X	
KY	X	
LA	X	
MA		X
MD		X
ME		X
MI	X	X
MS	X	X
MO		X
MT	X	X
ND	X	
NE	X	X
NH		X
NJ		X
NM	X	
NY	X	X
OH	X	
OK	X	
OR	X	
SC	X	
SD	X	
TX	X	
VT		X
VA	X	X
WA	X	X
WI	X	
WY	X	

Table C-15. Is Approach Slab Settlement a Significant Problem?

State	Yes	No	Moderate
AZ		X	
CA	X		
CT			X
DE	X		
FL			X
GA	X		
ID	X		
IN			X
IA			X
IL	X		
KS	X		
KY	X		
LA	X		
MA			X
MD			X
ME		X	
MI			X
MN	X		
MS	X		
MO	X		
MT	X		
ND	X		
NE	X		
NH		X	
NJ			X
NM	X		
NY			X
OH			X
OK	X		
OR	X		
SC	X		
SD	X		
TX		X	
VT		X	
VA			X
WA	X		
WI	X		
WY		X	