توێژینەوەی دروستکردنی پرد بەبێ (Expansion joint)

یان کەم کردنەوەی

مەبەست لەم توێژینەوەیە دروست کردنی پردە کە بتوانرێ کەمترین جۆینت و (Elastomeric bearing) ی تیا بە کاربهێنرێت یان هەر نەهێڵرێت.

هەروەك ئەزانرێت (Expansion joint) لە پردەکاندا زۆر زوو پێویستیان بە گۆڕین و چاکسازی هەیە بە تایبەتی بەهۆی خراپ دانانیان و جۆری جۆینتەکان لە ماوەیەکی کەم دا بەرز ئەبنەوە ئەبێتە هۆی مەترسی لە بەکارهێنانی پردەکاندا.

بێجگە لەوەی کە تێچونی سەرەتایی زۆرەو پێویستە لە دەرەوەی وڵات هاوردەبکرێ تێچونی چاکسازی و گۆڕانکاریان ساڵ لە دوای ساڵ زیاتر ئەبێت .

هەر بۆیە لە وڵاتانی دنیاو لە ئەمەریکا زۆر هەوڵدراوە کە بتوانرێ پردەکان بە جۆرێك دیزاین بکرێت کە جۆینتی تیا نەمێنێ و یان کەم بکرێتەوە .

وە لە هەمان کاتدا ئەتوانرێ ژمارەی بێرنەکان کەم بکرێتەوە یان نەهێڵرێت کە بە هەمان شێوە بێرنەکان پێویستی بە تێچونی سەرەتای زۆرەو ئەبێت لە دوای نزیکەی ٢٠ ساڵ بگۆڕێت.

بۆیە بە پێویستم زانی هەم توێژینەوە لەو بارەیەوە بکەم و ئەم بابەتە بوروژێنم وە هەم بە شێوەیەکی فعلی بیخەمە بواری جێبە جێ کردنەوە کە لە دیزاین کردنی پردەکانی داهاتوومان‌دا ڕەنگ بداتەوە.

لەگەڵ ڕێزدا.....

سەروکی ئەندازیاران / بەشی دیزاین

محمد صابر سعید

CONTENTS

PURPOSE OF RESEARCH

JOINTLESS BRIDGES

MOHAMMAD SABER SAAID
STRUCTURE DESIGNER ENGINEER
GENERAL DIRECTORY OF ROAD,
CONSTRUCTION AND HOUSING
OF SULAYMANIYA
DEPARTMENT OF DESIGN
TELEPHONE (07707711921)

Abstract
There are many advantages to jointless bridges as many are performing well in service.
There are long-term benefits to adopting integral bridge design concepts and therefore there should be greater use of integral bridge construction. Integral abutment and jointless bridges cost less to construct and require less maintenance then equivalent bridges with expansion joints. This paper explains why we should use Integral Abutment and Jointless Bridges, and discusses some of the recommended practices for Integral Abutment and Jointless Bridges.

Why Jointless Bridges?
One of the most important aspects of design, which can affect structure life and maintenance costs, is the reduction or elimination of roadway expansion joints and associated expansion bearings. Unfortunately, this is too often overlooked or avoided. Joints and bearings are expensive to buy, install, maintain and repair and more costly to replace. The most frequentlyencountered corrosion problem involves leaking expansion joints and seals that permit salt-ladenrun-off water from the roadway surface to attack the girder ends, bearings and supportingreinforced concrete substructures. Elastomeric glands get filled with dirt, rocks and trash, andultimately fail to function. Many of our most costly maintenance problems originated with leakyjoints.
Bridge deck joints are subjected to continual wear and heavy impact from repeated liveloads as well as continual stages of movement from expansion and contraction caused bytemperature changes, and or creep and shrinkage or long term movement effects such assettlement and soil pressure. Joints are sometimes subjected to impact loadings which can exceedtheir design capacity. Retaining hardware for joints are damaged and loosened by snowplowsand the relentless pounding of heavy traffic. Broken hardware can become a hazard to motorists,and liability to owners.
Deck joints are routinely one of the last items installed on a bridge and are sometimes notgiven the necessary attention it deserves to ensure the desired performance. While usually not asignificant item based on cost, bridge deck joints can have a significant impact on a bridgeperformance. A wide variety of joints have been developed over the years to accommodate awide range of movements, and promises of long lasting, durable, effective joints have led Statesto try many of them. Some joint types perform better than others, but all joints can cause maintenance problems.
Bearings also are expensive to buy and install and more costly to replace. Over time steelbearings tip over and seize up due to loss of lubrication or buildup of corrosion. Elastomeric bearings can split and rupture due to unanticipated movements or ratchet out of position.

Because of the underlying problems of installing, maintaining and repairing deck jointsand bearings, many States have been eliminating joints and associated bearings where possibleand are finding out that jointless bridges can perform well without the continual maintenance issues inherent in joints. When deck joints are not provided, the thermal movements induced inbridge superstructures by temperature changes, creep and shrinkage must be accommodated byother means. Typically, provisions are made for movement at the ends of the bridge by one oftwo methods: integral or semi-integral abutments, along with a joint in the pavement or at theend of a reinforced concrete approach slab. Specific guidelines for designing and detailing jointless bridges have not yet been developed by AASHTO so the States have been relying onestablished experience.

A 1985 FHWA report on tolerable movement of highway bridges examined 580abutments in 314 bridges in the United States and Canada. Over 75 percent of these abutments experienced movement, contrary to their designer's intent. (R5)

In this 40-year national experience, many savings have been realized in initial construction costs by eliminating joints and bearings and in long-term maintenance expensesfrom the elimination of joint replacement and the repair of both super and substructures.Designers should always consider the possibilities of minimum or no joint construction toprovide the most durable and cost-effective structure.

Steel superstructure bridges up to 400 ft.long and concrete superstructure bridges up to 800 ft. long have been built with no joints, even at the abutments. (R6)*

The following quote is very appropriate for bridge engineering:

"Quality is never an accident. It is always the result of high intention, sincere effort,intelligent direction, and skillful execution. It represents the wise choice of many alternatives."

This is especially true when the Engineer begins the task of planning, designing and detailing a bridge structure. The variables are many, each of which has a different, first and lifecycle, cost factor. The question to be asked continuously through the entire process is what valueis added if minimum cost is not selected? Another question to be asked is what futures should be incorporated in the structure to reduce the first and life cycle cost and enhances the quality? Mostof the variables are controlled by the designer. These decisions influence the cost and quality ofthe project; for better or for worse!

This paper presents some of the important features of Integral abutment and Jointlessbridge design and some guidelines to achieve improved design. The intent of this paper is toenhance the awareness among the engineering community to use Integral Abutment and Jointless Bridges wherever possible.

*** R Stand for Reference**

What Is an Integral Abutment Bridge?

Integral abutment bridges are designed without any expansion joints in the bridge deck.

They are generally designed with the stiffness and flexibilities spread throughout thestructure/soil system so that all supports accommodate the thermal and braking loads. They aresingle or multiple span bridges having their superstructure cast integrally with their substructure.

Generally, these bridges include capped pile stub abutments. Piers for integral abutment bridgesmay be constructed either integrally with or independently of the superstructure. Semi-integralbridges are defined as single or multiple span continuous bridges with rigid, non-integral foundations and movement systems primarily composed of integral end diaphragms,compressible backfill, and movable bearings in a horizontal joint at the superstructure-abutmentinterface.

The following drawing are belongs to projects constructed or under construction. Calculate the total elongation of thermal expansion in the bridge deck evaluate with allowable strain of the materials (steel or concrete) and the lateral force produced from thermal expansion. The designer gagmen decide what type of abutment could be used.

Fix joint or fix abutment is joining movement between superstructure and substructure the thermal movement force transfer to substructure.

Semi expansionor (Semi-integral abutment) works partial movement of superstructure over abutments without transfer the moment from superstructure to substructure at abutments.

Free joint or free expansion is allowed the free movement of thermal expansion without transfer movement to the superstructure. This type of joint could be hiding under the slab as shown below.

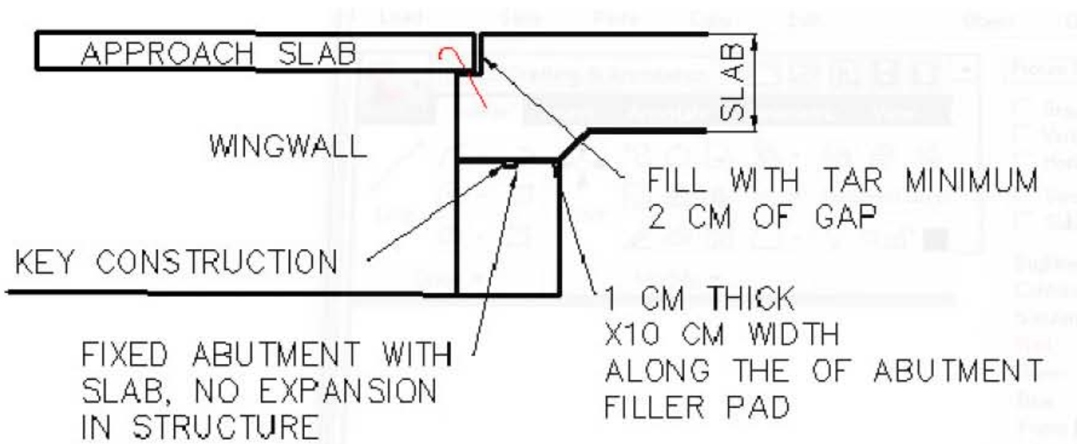


FIGURE 1 Fixed Abutment no expansion joint on the bridge.

This type of fixed abutment has been experienced in my new bridge design for Proven of Sulaymania (Zahrawabridge in Rania and ChanakhchianbridgeinArbut) works great.

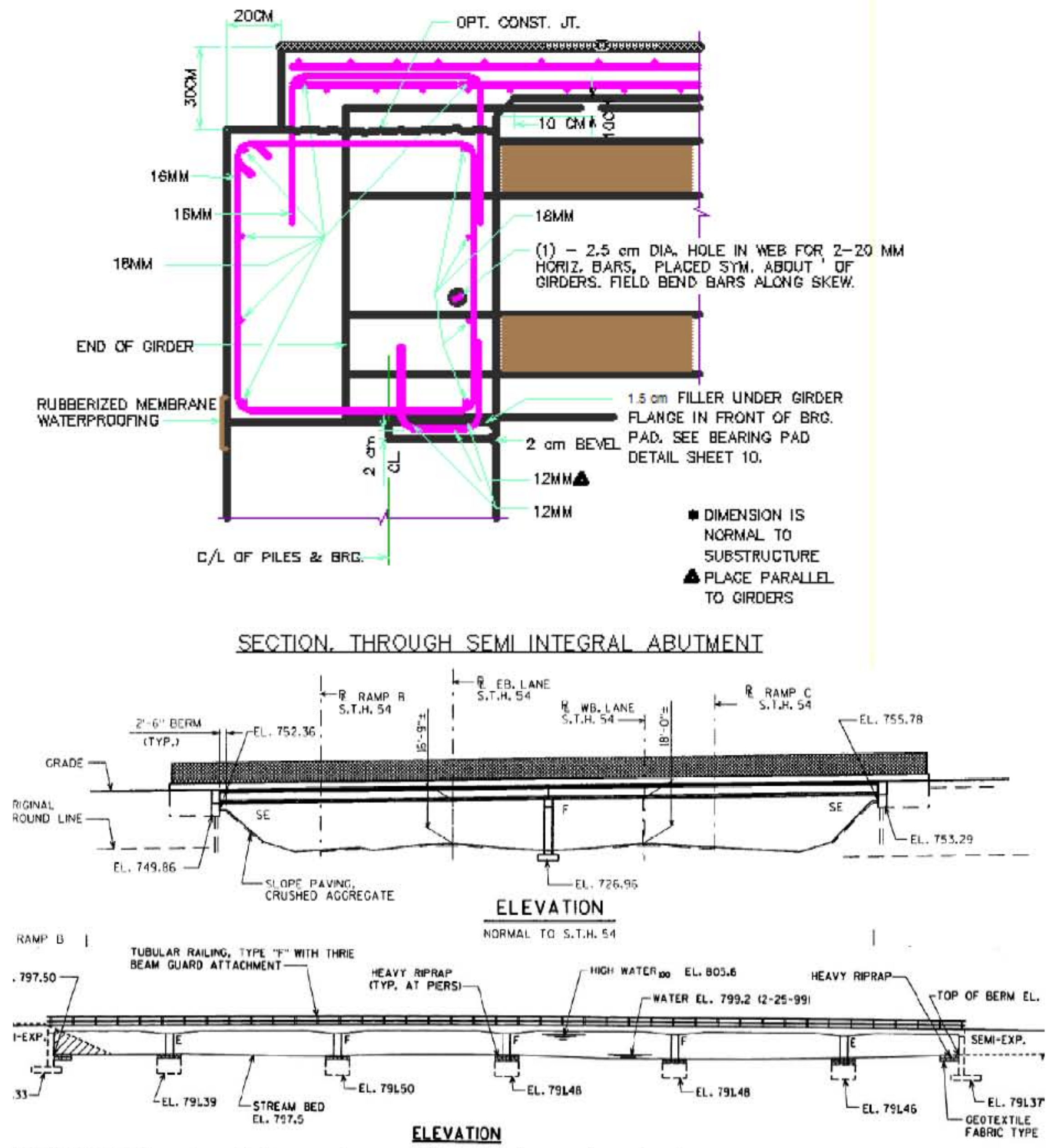


FIGURE 2-mix of fix and semi fix abutment and pier

Two example of my design for jointless bridges one with semi expansion at abutments 80 meter length pre-stressed girder and other one 6 spans with fix at abutments, total length 100 meter.

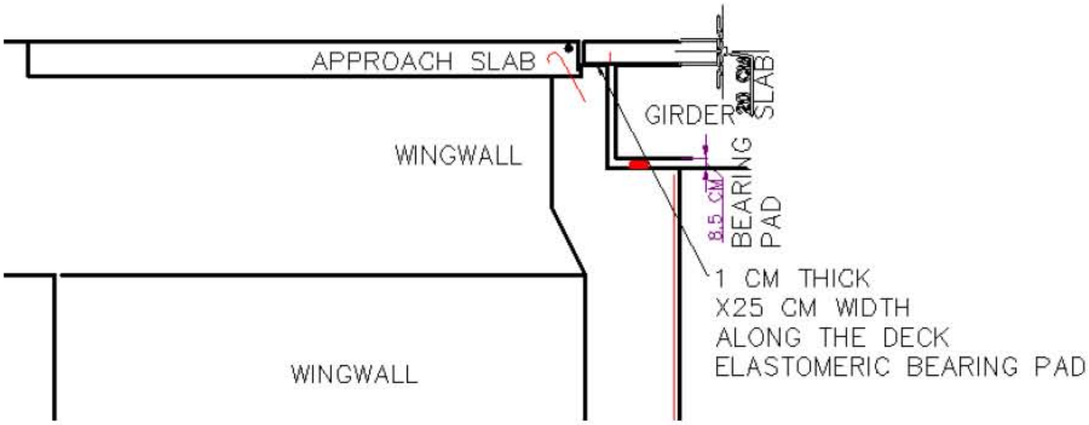


FIGURE-3 Free movement with hidden gap under slab to avoid expansion joint at abutments.

This type of bridge is experienced in my design of ChaqChaqbridge in Sarchinar-Sulaymania.

Advantage of jointless and Why jointless (fixed and semi-fixed abutment)?

As stated earlier, integral abutment and jointless bridges cost less to construct andrequire less maintenance than equivalent bridgeswith expansion joints. In addition to reducing first costs and future maintenance costs, integral abutments also provide for additional efficiencies in the overall structure design.Integral abutment bridges have numerous attributes and few limitations. Some of themore important attributes are summarized below.

Simple Design - Where abutments and piersof a continuous bridges are each supported by asingle row of piles attached to the superstructures,or where self-supporting piers are separated fromthe superstructure by movable bearings, an integralbridge may, for analysis and design purposes, beconsidered a continuous frame with a singlehorizontal member and two or more verticalmembers.

Jointless construction –Jointless construction is the primary attribute of the integral abutment bridges. The advantages of jointless construction are numerous as has been statedearlier.

Rapid construction - Only one row of vertical piles is used, meaning fewer piles. Theback wall can be cast simultaneously. Fewer parts are required. Expansion joints and bearings are not needed. The normal delays and the costs associated with bearings and joints installation,adjustment, and anchorages are eliminated.

Ease in constructing embankments - Most of the embankment is done by large earthmoving and compaction equipment requiring only little use of hand operated compaction equipment.

No cofferdams - Integral abutments are generally built with capped pile piers or drilled shafts piers that do not require cofferdams.

Vertical piles (no battered piles) - At abutment a single row of vertical piles is used.

Simple forms - Since pier and abutment pile caps are usually of a simple rectangle shapethey require simple forms.

Few construction joints are required in the integral abutment bridges which results inrapid construction.

Reduced removal of existing elements - Integral abutment bridges can be built aroundthe existing foundations without requiring the complete removal of existing substructures.

Simple beam seats - Preparation of load surface for beam seat can be simplified oreliminated in integral bridge construction.

Greater end span ratio ranges - Integral abutment bridges are more resistant to uplift.
Integral abutment weight acts as counterweights. Thus, a smaller end span to interior span ratiocan be used without providing for expensive hold-downs to expansion bearings.

Simplified widening and replacement - Integral bridges with straight capped-pilesubstructures are convenient to widen and easy to replace. Their piling can be recapped andreused, or if necessary, they can be withdrawn or left in place. There are no expansion joints tomatch and no difficult temperature setting to make.The integral abutment bridge is act as a whole unit.

Lower construction costs and future maintenance costs.

Improved ride quality - Smooth jointless construction improves vehicular riding qualityand diminishes vehicular impact stress levels.

Design efficiency - Design efficiencies are achieved in substructure design. Longitudinaland transverse loads acting upon the superstructure may be distributed over more number ofsupports.
For example, the longitudinal load distribution for the bent supporting a two span bridgeis reduced 67 percent when abutments are made integral instead of expansion. Depending uponthe type of bearings planned for an expansion abutment, transverse loadings on the same bent can be reduced by 67 percent as well.

Added redundancy and capacity for catastrophic events - Integral abutments provideadded redundancy and capacity for catastrophic events. Joints introduce a potential collapse mechanism into the overall bridge structure. Integral abutments eliminate the most commoncause of damage to bridges in seismic events, loss of girder support. Integral abutments haveconsistently performed well in actual seismic events and significantly reduced or avoidedproblems such as back wall and bearing damage, associated with seat type jointed abutments.Jointless design is preferable for highly seismic regions.

Improve Load distribution - Loads are given broader distribution through thecontinuous and full-depth end diaphragm.

Enhance protection for weathering steel girders
Tolerance problems are reduced or eliminated - The close tolerances required withexpansion bearings and joints are eliminated or reduced with the use of integral abutments.

What is the joint and functionality

The term "expansion joint" as used throughout this report refers to the joint provided permit the separate segments of the structural frame to expand and contract in response to temperature changes without adversely affecting the building's structural integrity or serviceability. So expansion joint is an assembly designed to safely absorb the heat-induced expansion and contraction of various construction materials, to absorb vibration, to hold certain parts together, or to allow movement due to ground settlement or earthquakes.

Function

Bridge expansion joints have to function as "riding plates" to carry the imposed traffic loads and also accommodate the thermal movement, shrinkage, pre-stress creep and rotation of the deck. These joints can be simple flexibilised asphalts or complex mechanical or elastomeric elements, according to the range of movements to be accommodated. The expansion joint should give good riding characteristics without generating excessive noise from traffic, especially in urban areas where adjacent residential property may need careful consideration. It must also be functional for the road user whilst having good skid resistance and be suitable for the road curvature and alignment. If pedestrians, animals and cyclists use a bridge the expansion joint should be of a design which does not cause safety problems. Footpaths may need cover plates slightly recessed below the surface to provide safe access.

Durability

It is essential to use materials which are durable and offer a maintenance-free operation. Any elements subject to wear must be replaceable using simple techniques since traffic management schemes and lane closures are costly and need special authorization as well as causing public irritation. Therefore, it may be expedient to replace bridge expansion joints prematurely while other maintence work, such as re-surfacing, is carried out so that future road closures are minimized.

CRITERIA ASPECT FOR DETERMINING THE NEED FOR EXPANSION JOINTSOR JOINTLESS BRIDGE

What is the principle behind jointless?

Concrete and steel has limited plasticity to able to return to its original shape after removing the acting force it is the strain of material. The strain of concrete and steel could be used to calculate the ability of movement the bridge members without any damage to structure.

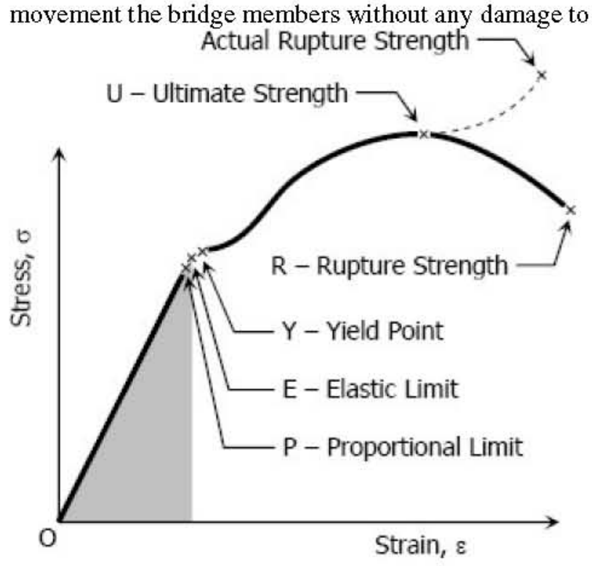


FIGURE-4 Stress-strain diagram of a medium-carbon structural steel (R5)

Allowable strain in concrete is 0.003, the length of pile, stiffness of pile and sub-grade reaction has large influence of the decision of the designer to make jointless structure.

TABLE-1 Lateral Load Capacity Table (from R4,6)

Recommended values of lateral resistance for battered or vertical piles used by the bridge section in lieu of the following detailed analysis are:

Soil condition	timber	10-3/4 inch steel casing pile-Concrete Cast in Place - CIP	12 inch Precast CIP	Steel H-pile
Poor	4k	7k	8k	7k
Average	5k	9k	11k	10k
Good	5k	9k	11k	15k

Structures supported by single piles or pile groups are frequently subjected to lateral forces from lateral he thermal movement has a lateral force on the structure with the other forces such as earth pressure, live load, wave action and wind forces. Pile subjected to lateral forces must be designed to meet the allowable stress and deflection criteria to prevent premature failure of foundation or superstructure. To solve the soil-structure interaction problem, the designer determines the following:

1-Characteristics of the pile including:
a-stiffness of the pile.
b-rotation restrictions imposed on the top by the cap.
c-maximum bending moment imposed on the pile and the distribution of the bending moment along the pile length.
d-probable points of fixity on the pile.
2-stiffness of the soil.
3-allowable deflection of the pile permitted by the superstructure.

Many theories for lateral load capacity are based upon Terzaghi's 1955 Theory of sub grade reaction.
The coefficient of horizontal subgrade reactor, Kh, is defined as
Kh = P/Y -------1 (R4)
Where Y is the lateral deformation at the point where the pressure is P tons per foot of width. For cohesionless soils and normally consolidated clays, Kh is assumed proportional to the depth. Therefore,
Kh=nh Z. --------2(R4)
Where nh is the constant of horizontal subgrade reaction at depth Z.
Combining equations 1 and 2, solving for the constant of subgrade reaction
nh = Px(l/(YZ)) ----- 3(R4)
in tons per square foot per foot of depth below the lowest adjacent surface.
A necessary parameter in the analysis is a term called the relative stiffness Factor, T, which is defined as
T = (EI/nh)1/5 -------4(R4)
Where E and I are respectively the modulus of elasticity and the moment of inertia of the pile section.
Another useful term is normalized length, Z max, which equals
Z max = L/T ----------5(R4)

Where L is the length of the pile. For large values of T and relatively small values of L, the term Z max is small and the pile acts like an infinitely rigid pole in this cause the designer should use expansion joint or hidden joint. However, for large L and relatively small T, the term Z max is large and the pile is relatively flexible. Experience indicates that except for extremely loose soils and/or very stiff piles, T is usually less than 6. These usual conditions include most timber, concrete, H-piles or steel pipes; and most sand and normally consolidated clays. This observation is illustrated in figure (11.2) which gives values of relative stiffness Factor, T for various pile stiffness and soil conditions, for a pile longer than 30 feet, Z max is generally greater than 5, the following simplified method is developed for the conditions corresponding to Z max greater than 5. This procedure is appropriate for most practical conditions likely to be encountered involving long piles.**For special applications of short piles or post, this simplified method does not apply.**This method follows the procedure developed by Matlock and Reese.

The computations are performed in the three step sequence given below using the monographic values given in Figures (11.2) to (11.5). from (R4,6)

Step 1- determine Z max to determine if this method applies, Z max must be greater than 5.

a-determine the EI of the proposed pile from table (11.3) or from actual data.

b- determine the value of nh for soil in tons per cubic foot from table (11.4) or from field test results.

c-from figure (11.2) read off T for the EI and nh values determined in (a and b).

d-compute L & T which in most practical cases is greater than 5. If this is so, continue with the following procedures.

Step 2- use monographic values given in figures (11.3) to (11.5) in order to compute maximum deflection under unit lateral load or unit moment for different pile cap fixity conditions.

Piles with rigid caps –unit horizontal Load---from (R6)

Figure (11.3) gives the maximum deflection under a l kip horizontal load applied at ground level for the given EI of the pile and (nh) of the soil. The maximum deflection occurs at the top of the pile. With this value for a given soil, compute the deflection for the given pile section and lateral load, compute the maximum lateral load for a given pile section and maximum allowable deflection, or compute the stiffness of the pile required for a given lateral load and allowable deflection.

Piles with flexible caps – unit horizontal load and unit moment

Figure (11.4) gives the maximum deflection (sp) of the pile due to a 1 kip horizontal load applied at ground level and figure (11.5) shows the maximum deflection (sm) of the pile due to 1 kip-ft. moment. Both the maxima occur at the ground surface, or at the top of the pile if below the ground surface, and are additive. With this value, compute maximum deflection for a given loading condition or compute the stiffness of the pile required for a given stress condition and allowable deflection.

Step 3- determine the maximum bending moment and point of zero deflection based on Matlock and Reese Theory.

Pile with rigid caps----from (R6)

a-the maximum bending moment on the pile is (– 0.92T) kip-ft. for a 1 kip horizontal load placed at the top of the pile and (+0.26T) kip-ft. at a depth of 2.15T from the top of the pile.

b- the point of zero deflection is 3.1T ft. below the top of the pile.

Pile with flexible caps--- from (R6)

a-the maximum bending moment on the pile may be taken as the larger of 0.98 M +0.45 PT kip-ft. at a depth of 0.5T ft. or 0.85M +0.73 PT kip-ft. at a depth of 1.0 T ft.
P is the lateral load and M is the externally applied bending moment,
b-the point of zero deflection may be taken at approximately 2.0T ft. below ground level.

Example in solving for jointless bridge:

The following example is given to illustrate lateral load from thermal expansion:
A 45 ft long one span bridge with fixed abutments.The abutments fix at top by the slab and at bottom by 5 10 3/4-inch diameter concrete cast in place pile (CIP).
The natural ground identify as medium stiff clay

The following lateral loadshad calculated during designing the bridge and given as follow:
live load = **7.7k**, earth load = 10k, longitudinal lane load= **1.17k**, wind load on structure = **0.63k**, wind load on live load=**1.8k**, estimate temperature change = 45 degree/F
To calculate for temperature load ;
Coefficient of thermal exp = 0.000006/F
dt=0.0000006x45x45ft= 0.0121 ft = 0.146 inch.
From that the structure expand 0.146 inch, by dividing the expand to both abutments each abutment should allowed for 0.146/2= 0.073 inch.
Thermal lateral force:
EI of 10-inch of CIP = $1.47x10^9$ from table (11.3) from (R4,6)
nh (constant of subgrade soil) for medium stiff clay= 8ton/cubic feet table (11.4)from (R4,6)The abutments are fix so use figure (11.3) to find the deflection for 1 kip lateral force.
Deflection (sp)= 0.056 inch
Thermal lateral force P = 0.073 x 1/0.056 x 5 piles = 6.51 k
Find the reaction of top of pile
RT (top reaction) = 7.7+10+1.17+0.63+1.8+6.51= 27.81k
Load on one pile = 27.8/5= 5.56 k < 9k for average soil (see Lateral Load Capacity Table-1)

Therefor the bridge resist all lateral forces include thermal load and not require expansion joint

Type	Shape	Size—in.	EI 10^6 lb.-in.^{2}	Assumption
Timber	round	12 16 20	1.53 4.82 11.78	$E_T = 1.5 \times 10^6$ psi
Concrete	round	10 12 16 18 24	1.47 3.06 9.65 15.42 48.78	$E_C = 3.0 \times 10^6$ psi
	square	12 18	5.18 26.22	
	octagonal	16 24	10.92 55.26	
Steel	H	HP 10 HP 12 HP 14	6.33 11.85 21.99	$E_s = 30.0 \times 10^6$ psi
	pipe	12 O.D. 16 O.D. 20 O.D.	8.38 16.86 33.40	

Stiffness for Various Piles

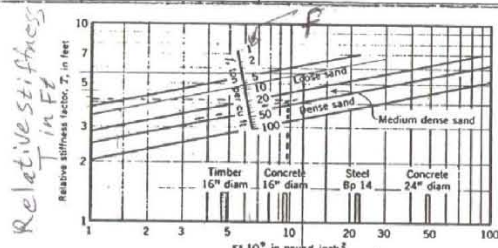
TABLE 11.3

Soil	Soil Characteristics	n_h in Tons/ft^3
Loose sand	Relative density = 30%	6 tons/ft^3
Med. dense sand	" " = 60%	30 tons/ft^3
Dense sand	" " = 80%	45 tons/ft^3
Soft clay	$q_u = 0.4$ T/ft^2	4 tons/ft^3
Med. stiff clay	$q_u = 0.8$ T/ft^2	8 tons/ft^3

Constant of Subgrade Reaction for
Various Soils

(From Naval Document DM-7 Design Manual 2)

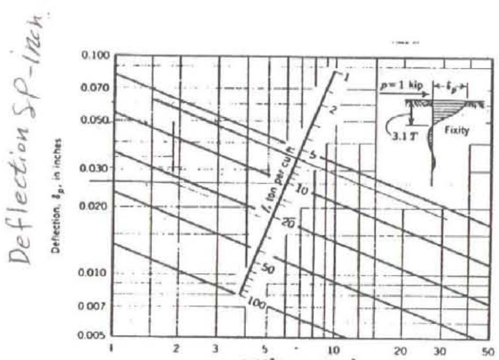
TABLE 11.4



Relative Stiffness Factor "T"

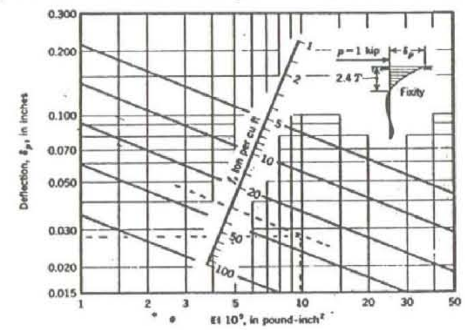
FIGURE 11.2

f = coefficient of Variation of Lateral Subgrade Reaction
f = ton / ft^3



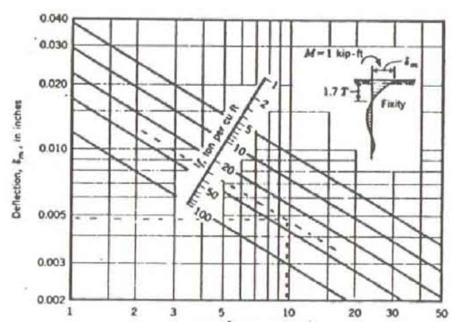
Maximum Deflection for Rigid Cap Pile Due to 1-kip Lateral Load

FIGURE 11.3



Maximum Deflection for Flexible Cap Pile
Due to 1-kip Lateral Load

FIGURE 11.4



Maximum Deflection for Flexible Cap Pile
Due to 1 kip-ft Moment

FIGURE 11.5

As a minimum, each of the following factors should be examined and taken into account duringexpansion joint location and design:
a. Dimensions and configuration of the bridge structure.
b. Design temperature change, which should be computed in accordance with the formula:

1. **Dimensions and Configuration of the structure bridge**
The dimensions of a structure bridge, types of foundation, columns and superstructures are obviously an overriding parameter with regard to the need for expansion joints and location.
Also the configuration of a structure is a parameter influencing the severity of the effects of temperature changes on a bridge and, as such, should be given consideration during the design process.

2. **Temperature Change**
Since construction is carried out over a considerable period of time, the various elements of the structure are installed at different temperatures. The temperature changes causing displacements and stresses in a structure are changes from these installation/erection temperatures, over which the designer has little, if any, control. Yet, while it is apparent that temperature change is one of the most important factors influencing the potential linear expansion/contraction of a building, there is no possibility of establishing exactly the maximum expected temperature change because this change is not the same for all parts of the structure and is not known during the design phase for any one particular part of the structure.

Computation of effective length L of bridge segments adjacent to the expansion joint

1. The width of the expansion joint should exceed the maximum potential dimensional changes by an amount sufficient to prevent the complete closing of the joint and, simultaneously, provide for construction tolerances and nature of filler material. The maximum potential dimensional change can be computed.

2. The upper bound, UB, of the maximum joint closing obviously will depend on the coefficient of thermal expansion of the material of the frame, the maximum temperature change (i.e., the effective temperature increase dte = Tw-Tm) that the structural frame is assumed to undergo, and the effective length, L, of the structural segments converging at the joints. The effective length, L, can be computed utilizing the following empirical guidelines in conjunction with Figure 5: (R5)

a. If both the bridge segments converging on the joint have symmetrical stiffness, only one half of the dimensional change of each segment will affect the joint separation (Figure5a), hence, L = 1/2 (L1+L2).

b. If, however, either segment has one end substantially stiffer than the other, the dimensional change resulting from temperature fluctuation will be distributed unevenly between the two ends of such a segment with comparatively less deformation developing at the stiff end. In such cases,
L = 1/2 (KL1+L2),
Where K = 1.5 (i.e., the length of the unsymmetrically stiff segment will be increased by 50 percent if the stiff end is farthest away from the joint; see Figure 5b) or K = 0.67 (i.e., the length of the unsymmetrically stiff end will be decreased by 33 percent if the stiff end is the one abutting the joint; see Figure 5c).

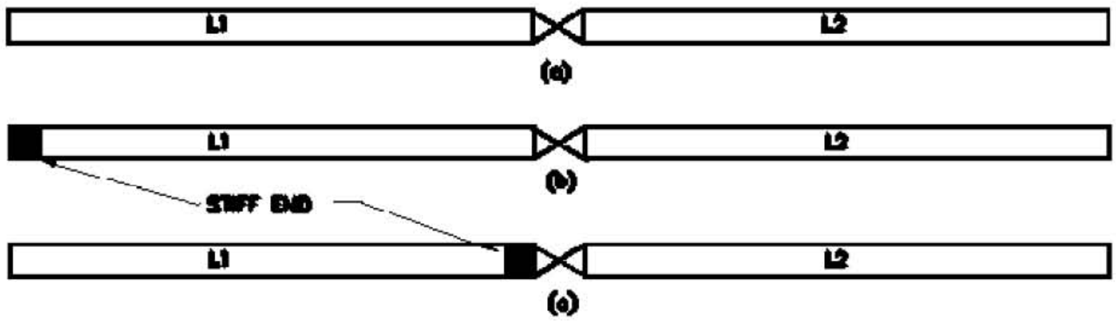


FIGURE 5Computation of effective length L of bridge segments adjacent to the expansion joint: (a bridge segments with symmetrical stiffness, L =1/2 (L1+L2);
(b) one segment with unsymmetrical stiffness and the stiff end farthest from the joint, L = 1/2 (1.5L1+L2);
(c) one segment with unsymmetrical stiffness and the stiff end abutting the joint, L =1/2 (0.67L1+L2).

The coefficient of thermal expansion of concrete and steel (the principal materials used for bridge & road) can be considered approximately the same and equal to 6·10` 6 per degree Fahrenheit.
The upper bound, UB, of the maximum joint closing can be computed from the expression:
UB = (6·10` 6) dtexL, where dte and L are as previously defined.

Thermal Movement (R3)
The maximum thermal movement required at expansion joints is based on the following temperature ranges and thermal coefficients.

Steel: -30 to 120°F -35 to 50°C	0.0000065/F	0.0000117/C
Concrete: +5 to 85°F -18 to 27°C	0.0000060/F	0.0000108/C
*Prestressed Girder: +5 to 85°F -18 to 27°C	0.0000060/F	0.0000108/C

* For Prestressed girders add shrinkage due to creep of .0003 ft/ft. (.0003m/m). This value should be used in setting the joint opening as the joint opening will continue to widen over time.

Recommended Best Practices

The following best practices are believed to contain the key elements to ensure qualityimprovements in designing and constructing Integral Abutment and Jointless Bridges.
· Develop design criteria or office practices for designing integral abutment and jointless bridges.
· In extending the remaining service lives of existing bridges, develop criteria forevaluating and retrofitting bridges with joints to integral or semi-integral structures.
Construction and maintenance of joints and jointless bridges since there is continuing innovation and changing technology. This will expertise of limited manpower in all the States and allow more effective communication of "What works and what does not".
· The decision to install an approach slab should be made by the Bridges and StructuresOffice, with consultation from the Geotechnical group. The decision should be basedupon long-term performance and life cycle costs, rather than just first costs to the project.

· Standardize practice of using sleeper slabs at the end of all approach slabs. An irregularcrack and pavement settlement typically develops at the interface of the approach slab andthe approach pavement. Develop a method to control and seal this cracking, and if notalready provided, develop a method to channel the water coming through this crack awayfrom the pavement without allowing material to be washed away.

Recommended Design Details for Integral Abutments (R1 to 5)

· Use embankment and stub-type abutments.
· Use single row of flexible piles and orient piles for weak axis bending.
· Use steel piles for maximum ductility and durability.
· Embed piles at least two pile sizes into the pile cap to achieve pile fixedly to abutment.
· Provide abutment stem wide enough to allow for some misalignment of piles.
· Provide an earth bench near superstructure to minimize abutment depth and wing walllengths.
· Provide minimum penetration of abutment into embankment.
· Make wingwalls as small as practicable to minimize the amount of structure and earththat have to move with the abutment during thermal expansion of the deck.
· For shallow superstructures, use cantilevered turn-back wingwalls (parallel to center lineof roadway) instead of transverse wingwalls.
· Provide loose backfill beneath cantilevered wingwalls.
· Provide well-drained granular backfill to accommodate the imposed expansion andcontraction.
· Provide under-drains under and around abutment and around wingwalls.
· Encase stringers completely by end-diaphragm concrete.
· Paint ends of girders.
· Caulk interface between beam and backwall.
· Provide holes in steel beam ends to thread through longitudinal abutment reinforcement.
· Provide temporary support bolts anchored into the pile cap to support beams in lieu ofcast bridge seats.
· Tie approach slabs to abutments with hinge type reinforcing.
· Use generous shrinkage reinforcement in the deck slab above the abutment.
· Pile length should not be less than 10 ft. to provide sufficient flexibility.
· Provide pre bored holes to a depth of 10 feet for piles if necessary for dense and/orcohesive soils to allow for flexing as the superstructure translates.
· Provide pavement joints to allow bridge cyclic movements and pavement growth.
· Focus on entire bridge and not just its abutments.
· Provide symmetry on integral bridges to minimize potential longitudinal forces on piersand to equalize longitudinal pressure on abutments.
· Provide two layers of polyethylene sheets or a fabric under the approach slab to minimizefriction against horizontal movement.
· Limit use of integral abutment to bridges with skew less than 30 degree to minimize themagnitude and lateral eccentricity of potential longitudinal forces.

Summary

There are many advantages to jointless bridges as many are performing well in service.
There are long-term benefits to adopting integral bridge design concepts and therefore thereshould be greater use of integral bridge construction. Due to limited funding sources for bridge maintenance, it is desirable to establish strategies for eliminating joints as much as possible andconverting/retrofitting bridges with troublesome joints to jointless design.
The National Bridge Inventory database notes that eighty percent of the bridges in the United States have a total length of 180-ft. or less. These bridges are well within the limit of totallength for integral abutment and jointless bridges. Where jointless bridges are not feasible,installation of bridge deck joints should be done with greater care and closer tolerances thannormal bridge construction to achieve good performance.

Since 1987, numerous States have adopted integral abutment bridges as structures ofchoice when conditions allow. At least 40 States are now building integral and/or semi-integralabutment type of bridges. Preference range from Washington State and Nebraska, where 80-90percent of structures are semi-integral; to California and Ohio, which prefer integral, but use mix,depending upon the application; to Tennessee, which builds a mix of both integral and semiintegral,but builds integral wherever possible. While superstructures with deck-end joints still predominate, the trend appears to bemoving toward integral. Although no general agreement, regarding a maximum safe-length forintegral abutment and jointless bridges, exists among the state DOTs, the study has shown thatdesign practices followed by the most DOTs are conservative and longer jointless bridges could be constructed.

There are several activities underway that will affect the way States are designing jointless bridges in the future. These include a joint AASHTO/NCHRP task force responsible forinitiating and drafting AASHTO design guide specifications and synthesis report on currentpractices for integral and semi-integral abutment bridges, FHWA-sponsored research study on Jointless Bridges, update of LRFD specs to address jointless bridge design issues, and futureworkshops. An excellent reference document on current issues regarding jointless bridges is theFHWA Region 3 Workshop manual on Integral Abutment Bridges, November, 1996.

Continuity and elimination of joints, besides providing a more maintenance free durablestructure, can lead the way to more innovative and aesthetically pleasing solutions to bridgedesign. As bridge designers we should never take the easy way out, but consider the needs of ourcustomer, the motoring public first. Providing a joint free and maintenance free bridge should beour ultimate goal. The best joint is no joint.

Conclusion

(1) General

All structure lengths. On skews over 45°, strip seals must be oversized to compensate for racking of the joint. For thermal movements greater than 4” (100 mm) modular expansion devices are recommended.

(2) Concrete Spans

An expansion device is required if the expansion length of the structure exceeds 300 feet (90 m). At this point the geometrics of the structure determine the number of expansion joints required with a maximum expansion length of 400 feet (120 m). The criteria established for abutments in Table 12.1 is applicable for structure expansion lengths if fixed piers are substituted for a fixed abutment. It is desirable to have at least two fixed supports within every expansion length.

As an example, consider a prestressed girder structure 700 feet (210 m) long on flexible piers and 0° skew. Considering the two piers near the center of the span as fixed, the structure can expand toward each abutment with maximum expansion lengths less than 400‘ (120 m). A 400 series model strip seal expansion joint at each abutment is adequate for this structure.

(3) Steel Spans

Watertight joints are required on all painted and unpainted steel structures to control staining of the substructure units due to corrosion of the steel girders, diaphragms, and bearings. An expansion device is considered if the expansion length of the structure exceeds 60’ (18 m) except single spans up to 150’ (45 m) with a skew angle equal to 5° or less do not require an expansion device. The geometry of the structure determines the number of expansion devices required and the amount of movement at each device.

Some factors to consider are temperature expansion with high skew angles may cause "racking" of the structure; higher abutments have more uncertainty to movement due to backfill pressure; and curved girders add torsional and shear forces. Long span structures on tall flexible piers may have much longer expansion lengths than short span structures on short rigid piers. The longer spans have much less resistance to horizontal temperature movement caused by bearing friction and pier rigidity. These types of structures are designed for joint movements of 4” (100 mm) or greater using modular expansion devices.

References

1. Wasserman, Edward P. and Walker, John H., “Integral Abutments for Steel Bridges,” October 1996.

2. Burk, Jr., Martin P., “An Introduction to the Design and Construction of Integral Bridges,” FHWA, West Virginia DOT and West Virginia University, Workshop on Integral Bridges, November 13-15, 1996.

3-Highways Agency Departmental Standard BD 33/94 and Advice
Note BA 26/94.Highways Agency publication SA/1 List of Approved/Registered Products includes bridge expansionjoints. It is revised annually

4-DM-7.01 SOIL MECHANICS by NAVAL FACILITIES ENGINEERING COMMAND

5-EXPANSION JOINTS INBUILDINGSTechnical Report No. 65
Prepared by the Standing Committee on Structural Engineering of theFederal Construction Council
Building Research Advisory Board
Division of Engineering
National Research Council - NATIONAL ACADEMY OF SCIENCES

6-State of Wisconsin Department of Transportation Bridge Manual