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Bridge Deck Expansion Joint Transition Areas

Réparation des zones proches des joints de dilatation de ponts

Instandsetzung der Fahrbahnübergangsbereiche bei Brücken

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SUMMARY

It has become apparent during the past decade on primary highway-bridge systems throughout the world that the wearing surface area and that structural portion of bridge decks directly underneath the surface which are adjacent to deck discontinuities tend to deteriorate under traffic loading and service conditions at a much faster rate than the main portion of the deck itself. This discussion will outline reasons for this phenomenon and describe recently developed materials and rehabilitative methodology that will operate towards extending the maintenance free life of this critical area of bridge decks.

RESUME

La surface de roulement et la partie de la structure de tabliers de ponts proches des joints, se détériorent plus rapidement sous l'effet du trafic et des conditions de service que la partie principale du tablier. L'article explique les raisons du phénomène et décrit les matériaux récent et les méthodes de réparation permettant de prolonger la période sans entretien de ces zones critiques de tabliers de ponts.

ZUSAMMENFASSUNG

Während des letzten Jahrzehnts zeigte sich in der ganzen Welt, dass sich der Zustand der Brückenfahrbahnplatten in der Nähe der Fahrbahnübergänge unter Verkehrslast viel schneller verschlechterte, als im ungestörten Bereich der Platte. Der Beitrag zeigt die Gründe für diese Erscheinung auf und beschreibt neu entwickelte Materialien und Instandstellungsmethoden, die die Lebensdauer dieser kritischen Bereiche verlängern und den Aufwand im Unterhalt herabsetzen.

1. INTRODUCTION

The ever recurring necessity to rehabilitate bridge expansion joints and the rapidly escalating cost of doing so in the face of continuing and spiraling inflationary pressures is becoming a serious problem for transportation engineers the world over.

The United States Federal Highway Administration in its March 1982 Highway Bridge Replacement & Rehabilitation Program report to the Congress of the United States advised that nearly one out of every two of the nation's 557,516 bridges are structurally deficient. The list is growing very rapidly and today 248,527 of these structures are substandard. This alarming statistic is being reflected in numerous bridge jurisdictions around the world.

As a result of this, life cycle cost thinking (the sum of first costs and in-service expenditures) is beginning to surface in the form of specifications which attempt to describe materials, methods of construction and rehabilitation which will either eliminate or greatly minimize the necessity for maintenance. To advance the state of the art requires an examination of the fundamentals involved, on a bridge by bridge basis, if we are to extend the maintenance free life of expansion joints which by far have been the major contributing factor to the early demise of bridges. It is also obvious that there is a critical need for some new materials and practices to take the place of the devices and systems which result in leaking joints, deteriorating interfacial joint surfaces, end dams which undergo premature post-installation cracking, eroding and spalling, or those that tend to break down under repetitive loading, snow plows, studded tires, chains and that in-service environmental chemistry peculiar to bridges.

This paper includes judgments that are the result of intensive investigational work and experience with bridge expansion joints over the past couple of decades including a time lapse analysis of numerous on-site photographs taken over this period of time as environmental and service conditions have taken their toll of performance of expansion joints.

1.2 Transition Area Defined

For purposes of this discussion, the commonly understood "end dam" or "nosing" component of the expansion joint is synonymous with and may be termed the "transition" area. That many of the materials in common usage today in the transition area have proven themselves historically to have short term performance capabilities is the subject of this report.

2. DESIGN GOAL

Using many present expansion joint materials and systems, the hoped for 50-80 year design service life idealized for bridges may be an impractical goal since less than 3 years is all that is necessary for many types of end dam components to fail. There is an apparent inability of certain types of end dam components to maintain any semblance of structural reliability for even the short term. It has also become apparent there is a need for a transition material to bridge the gap between the structural performance requirements of the main portion of the bridge deck and the expansion joint itself which in terms of dynamics are vastly different. For a split portion of a second, a heavy truck or lorry passing over a joint at high speed becomes partially airborne with the impact effect applied to the opposing joint interface taking its toll of structural life.

If one adds to this the impact effect at lowered temperatures upon the anchorage, expansion bolts, adhesives and the materials normally used in expansion joints when under tension in a contracted state, there is an obvious need for a re-examination of what types of materials could have a lengthening effect on service life.

With many expansion joints being hybrid devices comprised of materials with widely different expansion coefficients, hardnesses, energy assimilating capabilities and adhesive properties, it is postulated that the transition area of the bridge deck should comprise a forgiving material that will be compatible with these inherently differing properties so that they will not of themselves self-destruct under normal conditions of service.

3. PRESENT FAILURE MODES - MATERIALS & PRACTICES

3.1 Exotic Cements and Mortars

Epoxy mortars have excellent properties in the laboratory as adhesives but as an expansion joint end dam, they have proven rather conclusively that they cannot retain their structural integrity for lengths greater than 3 feet (1 m) in the classical end dam configuration. Pure epoxies have an expansion coefficient in the magnitude of 10 times greater than steel or concrete and while this can somewhat be ameliorated by aggregate loading, for all practical purposes they are incompatible for use in the transition area. They exhibit low tensile strength in the medium to high temperature ranges, significantly reduced strengths at lowered temperatures and are basically non-energy absorbing. Add to this problems in installation such as exotherm boiling, bond shear failures due to volume changes from thickness exotherm, plus mixing, proportioning and moisture complications and you can understand their early demise in deck transition areas.

3.2 Magnesium Phosphate Dams

Extensive failures of this type of exotic mortar when used in the classical end dam configuration appear to indicate that they may be incompatible when used with expansion joint devices. They have wide disparities in expansion coefficients prior to aggregate loading by a factor of 10 times as compared to the base deck concrete and it has been suggested that placing such hard brittle mortars in this environment is likened to "pouring glass on top of concrete" [1].

3.3 Polymer Concrete End Dams

In at least one comparison field test now 3 years old, polymer concrete end dams exhibited a disappointing service record. Donnaruma [2] in his report to the 1981 World Congress on Expansion Joints & Bearings concerning a controlled test environment on the Tappan Zee Bridge near New York City, elaborates on its high potential towards premature cracking under the 100,000 vehicle per day traffic density of this structure, 25% of which are trucks.

3.4 Portland Cement End Dams

It is the nature of Portland Cement when used in the shape of an end dam to exhibit longitudinal cracking initially at about 3 feet (1 m) intervals in similarity to epoxies, magnesium phosphates, and other exotic mortars. In the passage of time and temperature cycling, intermediate cracks continue to occur after which broken segments tend to work out under traffic loading. For this reason alone, it is an unsuitable material for use as a concrete end dam where leakproofing is the criteria.

3.5 Asphaltic End Dams

It would probably be safe to say that the "buried joint" or asphaltic transition dam concept which has seen extensive usage all over the world in every conceivable type of environment has been responsible for maintenance resurfacing costs to bridge decks beyond all calculation.

In the present state of the art, there exists no field-proven method of eliminating the inevitable crack or rip in the wearing course as time, temperature cycling and loading gradually break down the asphalt. This is much more quickly demonstrated in low temperature environments when the glasslike properties of asphalt when being stretched over a joint while in the contracted state becomes apparent.

3.6 Metallic Dams Cast-in-Place

While metallic dams which are cast-in-place monolithic through the deck from curb to curb are more desirable than those placed in segments, which tend to cause reflection cracks at junctures, they still are plagued with problems caused from differential movement coefficients, consolidation of concrete under flat members plus corrosion and weld fatigue failures of the anchorages which cause them to rock and work under live loads. Segmental metallic dams which are bolted in place are particularly troublesome and prone to becoming loose, a problem much in evidence on high truck density structures.

3.7 Corrosion Bursting of Expansion Joint Anchorages

Not unlike the problem of bridge decks which have a demonstrated propensity for premature failure due to purpose applications of chloride, acid rain and environmental chemistry which also tends to accumulate on the expansion joint, the embedded metals which comprise the expansion joint anchorage have the exact same problem. The use of elastomeric concrete eliminates the problem of anchorage corrosion completely since the electrolitic process necessary to oxidic degradation of base metals is totally occluded by embedment in an impervious rubber structure. As the use of elastomeric concrete continues to escalate, and costs by reason of volume usage declines, it is surmised that the entire bridge deck surface or wearing course will become a candidate market area because its properties appear to be ideal for the service requirements of a crack free impervious wearing course.

3.8 The As-Placed Temperature Problem

Since there are wide variations and constantly changing diurnal deck temperatures from early morning to mid-day to evening, the problem of placing exotic mortars, magnesium phosphates and epoxy systems which have widely differing expansion coefficients than the previously placed deck concrete, can have a large effect on their ability to remain crack free. It would be pure luck if an epoxy mortar, which has a 6 times greater coefficient of expansion than the base concrete it is positioned upon, was placed when the air temperature, deck temperature and the epoxy temperatures were similar.

Obviously the greater the temperature disparity between the deck and the end dam matrix as placed, the greater the tendency to longitudinal cracking since the two materials would be out of phase. Since there is no truly reliable means of taking a bridge deck temperature nor is there in fact any one single temperature throughout the mass of a bridge deck, it would be desirable to use something forgiving or elastic in this environment that could remain crack free regardless of these uncontrolled temperature differentials at time of placement.

4. PERFORMANCE CRITERIA FOR A TRANSITION DAM

Based on the heretofore described problem areas for transition dams, the following performance criteria seems indicated for an idealized transition dam:

1) It must be capable of being installed in one monolithic section for idealized leakproofing, extending throughout the impact area of the deck.
2) It must comprise an energy absorbing matrix to attenuate and absorb within itself anticipated impact loads.
3) Fastening it to the deck end must be achievable with a high degree of permanency.
4) An intimate impervious mating of the dam to the deck and adjacent wearing course is desirable to prevent rocking under live loads.
5) The end dam must be compatible with adjacent materials so as to preclude differential shrinkage or expansion movement and shearing.
6) The material should resist attrition, spalling, cracking or breaking down under impact and wear.
7) It should be chemically inert to typical bridge deck chemicals such as chlorides, sulphuric acid, the chemistry of acid rain, sunlight, soil bacteria, animal wastes and effects of ultra violet or ozone.
8) It must remain flexible and structurally sound during extremes of high and low temperatures.
9) It must seal out the entry of deleterious chemistry into the anchorage and fastening components.
10) All vertical and horizontal directional changes in the line of the expansion joint and all junctures resulting from lane-at-a-time rehabilitation requirements must be imperviously sound and structurally the equivalent of the main portion of the transition area.

5. THE DEVELOPMENT OF ELASTOMERIC CONCRETE AS A TRANSITION DAM

By en large due to the aforementioned expansion joint transition area problems, experimentation began in the early 70's in France with a new type of material which incorporates the desirable structural properties of sound concrete but also a fundamental elastomeric or rubberlike nature as well. Prior to 1970, the Boulevard Peripherique which encircles the City of Paris with its record truck traffic volume was experiencing intensive breakout failures of its expansion joints. In spite of a husky anchorage specification requirement of 7 tons per foot (20,834 kg/m) of bolt prestressment, heavy truck traffic was knocking out expansion joints en masse in less than 5 years of service. Experimental rehabilitation installations of joints utilizing a new type of material for transition areas, the generic description of which is "elastomeric concrete", which were installed in 1972 are still performing with excellence, apparently unaffected after over a decade of service in one of the world's most high density truck traffic environments. Since then extensive installations of elastomeric concrete have seen successful use in France and in a number of other countries including U.S.A. and Canada. The oldest installations are still structurally sound, have proven to be totally devoid of cracks as well as maintenance free and cost effective.

6. ENGINEERING PROPERTIES OF ELASTOMERIC CONCRETE

Extensive laboratory testing of elastomeric concrete reveals that it has an exceptionally high bond strength to concrete, asphalt and steel not only at room temperature but also high and low temperature exposures. Its rubberlike properties tend to negate the effect of live load impact stresses and absorb them like a vibration damper. It reacts to hammer blows similar to that of a rubber bearing pad and has the field demonstrated capability of remaining crack free in the typical end dam configuration for the life of the installation.

7. INSTALLATION OF ELASTOMERIC CONCRETE

The work process for elastomeric concrete minimizes rehabilitation time and effort. Vulcanization time depending upon ambient temperature is approximately 2 hours after which it may be opened to full design traffic loading. There is no interference with asphalting operations nor is there a necessity to remove deck concrete or drill into existing concrete.

The problem of drilling for anchorage bolts wherein embedded prestressment cables, hardware or reinforcing bars might be in jeopardy has been eliminated. Live load impact stress is distributed and attenuated throughout the mass of an elastomeric concrete dam. Corrosion of the expansion joint anchorage is eliminated because it is embedded in a mass of impervious rubber.

Since it is required that very high quality rubbers are used, a mobile field unit is utilized to field mix and blend a multicomponent mixture of vulcanizable elastomeric ingredients together with clean graded and powdered aggregates. These different components must be individually elevated and held at predetermined differential temperature gradients immediately prior to placement and field vulcanization.

Field vulcanization follows after placement by means of covering the expansion joint area with segmental heat chambers. The expansion joint system is heat fusion bonded to the subdeck as a by-product of elevated temperatures necessary to vulcanizing for a 2 hour period of time. The result is a monolithic, energy absorbing, permanently crack and spall free, impervious expansion joint end dam which has a long service life capability in the heaviest of truck traffic environments.

8. CONCLUSION

Present generation end dams or transition areas of bridge decks have tended to have a short performance life particularly in high density traffic environments Elastomeric concrete with over a decade of performance history offers a new tool for the bridge designer of expansion joints to extend the maintenance free life of his structure.

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