Research Report
KTC-04-20/SPR 179-98-1F

KENTUCKY TRANSPORTATION CENTER

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EVALUATION OF THE SERVICE PERFORMANCE OF BRIDGE COMPONENTS

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Research Report
KTC-04-20/SPR-179-98-1F

Evaluation of the Service Performance

Of

Bridge Components

By

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in cooperation with

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<tr><td colspan="4">16. Abstract
This study was initiated to provide review of common bridges to determine the performance of their components. Seven bridge types were selected that constituted 85 % of the Kentucky Transportation Cabinet (KYTC) bridge inventory. 319 bridges were inspected by Kentucky Transportation Cabinet (KTC) researchers, representing 5 about % of those bridges. Common details/components were identified and evaluated including features of interest to the KYTC Study Advisory Committee. In addition to those findings, KTC researchers evaluated KYTC National Bridge Inventory reports and maintenance needs forms for the same bridges.

Design modifications/material changes were recommended to improve performance of new bridges. Additionally, remedial measures were identified that would enhance the durability of existing bridges. Recommendations were also provided that would permit a more proactive approach to bridge maintenance activities.</td></tr>
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EXECUTIVE SUMMARY

Background

This study was initiated to provide an encompassing review of common bridges and determine the performance of their components. Representative examples of major bridge types were inspected and common details/component performance was identified. Thereafter, design modifications or material changes were recommended to enhance durability of existing and future bridges. Additionally, remedial measures were recommended that would minimize repair costs or enhance service performance. Recommendations were provided that would permit a more proactive approach to bridge maintenance activities for both current and past bridge types.

In reviewing the study work plan, the Study Advisory Committee (SAC) asked KTC researchers to focus on twelve bridge features of interest to SAC members including: 1) expansion joints, 2) barrier wall joints, 3) epoxy sand slurries, 4) concrete surface coatings, 5) bearings, 6) approach slabs, 7) deck overlays, 8) abutments, 9) stay-in-place forms, 10) deck drains, 11) galvanized and non-galvanized steel components, and 12) deck sealants.

KTC Bridge Inspections

As part of the study tasks, KTC researchers reviewed the KYTC National Bridge Inventory file at the KYTC Division of Operations. At the time of that analysis, 1999, KYTC possessed 6,476 bridges (excluding culverts). Inspection of the data revealed that 7 bridge types accounted for 5,511 of those bridges (85 %). Those bridge types are listed in Table 1. KTC researchers elected to focus their field inspections on those bridges.

KTC researchers inspected bridges in 8 Central Kentucky counties (Anderson, Clark, Fayette, Franklin, Jessamine, Montgomery, Scott and Woodford). Those counties had 375 of the 7 types of bridges. Three hundred and nineteen (85.1 %) of them were inspected. The totals and % ages for all types inspected by KTC are shown in Table 3. Overall, 5.78 % of all KYTC bridges in the 7 bridge types were inspected; with the % ages inspected ranging from 3.56 % for Type 505 bridges to 11.52 % for the Type 204 bridges. That work was conducted in 1998.

KYTC and KTC Bridge Data

KYTC Bridge Inspection Report Forms were obtained for the bridges inspected. Those reports were for inspections performed from 1994-1997. The bridge condition rating data on those forms is summarized both by bridge types and by bridge components in Tables 4-12. KYTC inspector comments provided on those forms are summarized in Table 13.

In 2004, KTC researchers visited the KYTC District 5 Office in Louisville to obtain recent information on bridges in Scott County and the KYTC District 7 Office in Lexington for bridges in Anderson, Clark, Fayette, Franklin, Jessamine, Montgomery and Woodford counties. Information from the District NBI files indicated that 28 of the original 319 bridges inspected had been removed from service. The District inspection records also indicated that 11 of the remaining bridges had been rehabilitated.

A comparison of KYTC condition ratings was made for the remaining active bridges to determine changes (decreases) over the period between the most recent available condition ratings (2001-03) and those initially provided to KTC (1994-97). That data is provided in Table 14 (for major bridge elements) and Table 15 (for specific deck components). As shown in Table 14, the average conditions ratings for the major bridge elements (decks, superstructures, and substructures) all decreased over the 7- to 8-year intervals between KYTC inspections/assessments. District 7 employs documents termed "General Maintenance Forms" that allow KYTC inspectors to indicate annual bridge maintenance needs to District bridge foremen. Table 16 provides a listing of bridge maintenance (and other) needs for the 7 bridge types in District 7.

KTC ratings for the bridge decks, bridge deck components, their performance and severity of various types of distress are provided in Tables 17-21. As shown in Table 17, the overall average deck condition for the 7 bridge types rated *good* to *very good* as did the overall ride quality. Beam/girder overall average condition ratings and distress ratings are provided in Table 22. The average overall condition of the beams and girders ranged from *good* to *very good* for the bridge types. Table 23 provides the average distress ratings for embankments and the condition/distress ratings for bridge abutments. The average embankment erosion ratings ranged from *fair* to *very good*. Average abutment overall condition ratings varied from *good* to *very good*. Pier average overall condition and distress ratings are provided in Table 24. The average overall condition ratings varied from *fai*r to *excellent*. Bridge average overall aesthetics and distress are provided in Table 25. The average overall aesthetics varied from *fair* to *very good*. The performance of specific bridge component types/designs is presented in Tables 26-33 including barrier walls, drains, deck joints, expansion devices, embankments, abutments, piers, and stay-in-place forms.

Conclusions

The following conclusions were reached for the 12 components of interest to the Study Advisory Committee.

1. Expansion/deck joints - The bridges in this study possessed a variety of deck joints/seals including the semi-open joints (sliding plates) and closed joints including poured-in-place asphalt, open compression seals, strip seals, poured-in-place silicon, segmental (or plank) seals, and modular joints. Both KTC and KYTC data obtained in this study have indicated that closed joints leak causing problems with underlying bridge elements.

2. Barrier wall joints - Barrier wall joints are intended to act as starter sites for barrier wall cracking similar to the joints in concrete sidewalks. Barrier walls were found to contain vertical through-thickness cracks not only at the joints, but also a few feet nearby indicating that the joints did not limit cracking in barrier walls. In some cases, barrier wall cracking was extensive and occurred far away from the joints.

3. Epoxy sand slurries - The epoxy sand slurries used in bridge deck gutter lines do not perform well. KTC data showed that they rated from *failed* to *poor* for the 7 bridge types.

4. Concrete surface coatings - KTC inspection data showed good overall performance from textured masonry coatings.

5. Bearings - KTC inspection data indicated few issues with bearings. The three bearing types observed - rockers, sliding plates, and bearing pads were all rated from *good*-to-*excellent*. The only problems involved corroded rockers that needed to be painted and a few rockers with excessive tilt.

6. Approach slabs - Approach slabs were not a common feature on the bridges inspected, being encountered on only 21 of 319 bridges. The data provided in Table 19 indicates that the approach slabs were performing as well as conventional approaches with the exclusion of moderate cracking noted on one Type 204 *concrete continuous tee beam* bridge. Approach slabs contributed to the overall ride quality over the bridge where they were employed. The ride quality on most bridges with approach slabs was rated from *very good* to *excellent*.

7. Deck overlays - KYTC NBI data on the relative performance of bridge decks contained in Table 10 indicated that deck overlays are performing nearly as well as non-overlain bridges for bridges of the same age (though the overlay may much newer). Over 10 % of bridge decks involved in this study were blacktopped, but apparently they did not incorporate the use of membranes to protect the underlying deck concrete.

8. Abutments - KTC abutment condition and distress ratings are provided in Tables 23 (overall ratings) and 31 (for individual abutment types). Two types of abutments were rated (full and stub). KTC was asked to determine the performance of spill-thru abutments which appear similar to stub abutments. The data indicated that the stub and full height abutments were performing similarly except for the Type 104 and Type 302 bridges, where the full-height abutments rated lower (in the *fair* to *good* range). Those bridge types included some older bridges with full height masonry abutments that may have contributed to the lower ratings than the bridges with stub abutments. KYTC has employed integral and semi-integral abutment bridges since 1970. Overall, abutment condition rating data shown in Table 31 indicates the KTC-classified integral abutments are performing as well as the non-integral or jointed bridges.

9. Stay-in-place forms - 18 bridges with steel stay-in-place forms were inspected. The KTC condition ratings are provided in Table 33. On four of those bridges, the stay-in-place forms were painted. The painted forms had *fair* to *good* condition ratings. Fourteen of the bridges had galvanized forms. Those were performing well with average condition ratings ranging from *very good* to *excellent*.

10. Deck drains - KTC drain condition and distress ratings are provided in Tables 20 (overall ratings) and 27 (for individual drain types). The KTC ratings indicated that the three types of drains inspected-slot (barrier) drains, scuppers and pipe (tube) drains-were performing satisfactorily for all of the bridge types. The average condition ratings for the three drain types were all *very good* to *excellent* for all 7 bridge types. However, several bridges contained small pipe drains that were clogged. In those cases, there was a large amount of debris in the gutter lines.

11. Galvanized and non-galvanized steel components - Galvanized protective end treatments and guardrails on barrier walls were rated. Eight painted end treatments and guardrails were inspected. They rated *poor* to *fair*. Several chain link non-galvanized fences on pedestrian bridges were rated *good*. The average condition/distress ratings for the galvanized end treatments guardrails are shown in Table 18. The average ratings for those due to corrosion and crash damage were all rated *very good.* The aluminum top rails used with some vertical concrete walls also were performing well.

12. Deck sealants - No recent KYTC applications could be identified. Transportation agencies in other states have used/are using a variety of sealants including silanes, siliconates, siloxanes, and methylmethacrylates to reduce concrete permeability and its related susceptibility to damage from moisture penetration and the percolation of chlorides to the depth of reinforcing steel.

Recommendations

The following recommendations are related to bridge design:

1. Discontinue the use of epoxy sand seals along bridge gutter lines.
2. Limit the use of deck joints on bridges and employ more new bridges with fully integral abutment designs.
3. When deck joints are required, use closed joints to the greatest extent possible (including modular expansion joints).
4. Use troughs under all deck joints including closed joints.
5. KTC is currently testing polymer concrete coatings that offer better performance than textured masonry coatings and tints. When that testing is completed and acceptable coatings are identified, they should be considered for routine use on new bridges.
6. Investigate erosion at bridge ends/approaches on bridges built to new KYTC Special Provision 69 to determine its effectiveness.
7. Improve inspection access to bridges by adding steps/walkways on embankments.
8. The KYTC Division of Bridges has employed a number of experimental features on bridges. Those features should be subject to long-term monitoring to assess their current performance.

The following recommendations are related to bridge maintenance:

1. KYTC is currently seeking to eliminate deck joints when conducting bridge rehabilitation projects. If joints cannot be eliminated, replace existing joints with a combination of closed joints and troughs where feasible. Investigate the performance of existing flexible and rigid troughs and consider the development of new trough designs.
2. Investigate the use of different joint seals such as polymer foams and asphalt plug joints. Where those joints have been used experimentally, conduct long-term monitoring to assess their performance.
3. Perform joint maintenance/repairs more frequently.

4. As previously noted, KTC is investigating protective coatings for concrete. When acceptable coatings are identified, they should be considered for use on existing bridge concrete to prevent deterioration.
5. Limit blacktopping to bridges that need eventual replacement or deck replacement. KYTC is currently expanding the use of asphalt membranes for overlay work especially on low ADT routes. Investigate the use of polymer overlays and polymer asphalts to supplement the use of latex concrete and asphalt membrane overlays.
6. Investigate the use of concrete sealers, crack fillers and spall patching materials for concrete maintenance (preservation) on bridges.
7. Employ concrete preservation materials (e.g. coatings, crack fillers, patching compounds and sealers) widely as part of a proactive preventive maintenance program.
8. Investigate the use of chloride extraction and cathodic protection to protect concrete bridge elements including decks, barrier walls, piers and abutments.
9. Increase steel bridge maintenance painting funding to a sustainable level. Employ spot painting to extend the service lives of existing bridge coatings.
10. Consider all options for bridge maintenance planning.
11. Employ General Maintenance Forms in all KYTC Districts and track implementation of inspector-recommended bridge maintenance actions.

INTRODUCTION

Background

Past KTC bridge research focused on the performance of experimental features including decks, coatings, bridge joints, integral abutments, drains and fasteners (1-5). While those studies provided useful insight on then-experimental or -current bridge features, they preceded recent innovations in design. Also, they did not address the performance of non-experimental components used in earlier bridge designs. KYTC officials believed that it would be beneficial to conduct a more encompassing review of common bridges to determine the performance of their components. Representative examples of major bridge types could be inspected and the performance of details/components/elements could be identified. This would verify the suitability of designs/components currently being used and identify any items that needed modifications or material changes to preclude problems on future bridges. Additionally, remedial measures could be identified that would minimize repair costs or provide enhanced performance. The findings of this review would also identify beneficial bridge maintenance activities.

This study was initiated to perform the field inspections, evaluate bridge component performance based upon that work, and provide recommendations for component design, material selection and maintenance.

Study Objectives

The objectives of the study were to:

1. categorize existing bridges and identify common bridge components of each bridge type;
2. conduct reviews of inspection/repair data and perform field inspections to assess the typical performance of representative components within each bridge category;
3. report the results of those reviews and inspections; and
4. provide recommendations for remedial practices or modifications to components of current designs and maintenance recommendations for components of past bridge designs.

This study was intended to provide a review focusing on the performance of components of common bridge types (current and past designs). The review considered some features and performance issues not addressed in the National Bridge Inventory Standard (NBIS) bridge inspections. Components/features of newer bridges were evaluated to provide KYTC with performance information that would assist in improving current designs or material selection to enhance the performance and serviceability of future bridges. The performance of components/ features of older bridge types were also assessed with the intent of recommending modifications to extend service their lives. Potentially beneficial preventive maintenance and rehabilitation procedures for those bridges were also considered. However, this study did not address scour, overtopping and most other waterway related issues.

Study Tasks

The following tasks were established for the study work plan:
Task 1. The Kentucky National Bridge Inventory (NBI) files were to be reviewed to identify bridge types and numbers of bridges in each category. In-depth inspection reports on common bridge types were to be reviewed to identify component service problems. Bridge personnel (Central office, District office, consultants, and field inspectors) were to be surveyed to identify component service problems. Maintenance histories and traffic data were to be reviewed

Task 2. From the assembled data, representative bridges for each category were to be selected for detailed analysis. Specific components/features of bridges (joints, bearings, coatings, approaches, transitions etc.) were to be identified for inspection/analysis.

Task 3. Representative bridges of current and past types in widespread service were to be inspected and their components assessed for performance. Maintenance histories and present conditions of in-service bridges were to be analyzed in conjunction with those inspections. Component shortfalls in performance were to be documented.

Task 4. Potential enhancements in component designs, material specifications, and workmanship were to be formulated for current bridge types. Maintenance and rehabilitation measures were to be developed for components of current and past types that warrant attention.

In reviewing the study work plan, the Study Advisory Committee asked KTC researchers to focus the inspections on:

1. expansion joints;
2. barrier wall joints;
3. epoxy sand slurries,
4. concrete surface coatings;
5. bearings;
6. approach slabs;
7. deck overlays;
8. abutments;
9. stay-in-place forms;
10. deck drains;
11. galvanized and non-galvanized steel components; and
12. deck sealants.

Work Performed Addressing the Study Tasks

Selection of Bridge Types to be Inspected

KTC researchers reviewed the KYTC National Bridge Inventory file at the KYTC Division of Maintenance. At the time of that analysis, 1999, KYTC possessed 6,476 bridges (excluding culverts). Inspection of the data revealed that 7 bridge types accounted for 5,511 (85 %) of those bridges. Those bridge types are listed in Table 1. The most common types of bridges were: 1) the Type 104 *concrete tee beam* (Figure 1), 2) the Type 505 *prestressed concrete, multiple box beam or girder* (Figure 2), 3) the Type 602 *prestressed concrete continuous multi-beam stringers or girders* (Figure 3), the Type 204 *concrete continuous tee beam* (Figure 4), the Type 302 *steel multi-beam stringer or girder* (Figure 5), the Type 402 *steel continuous stringer or multi-beam stringer or girder* (Figure 6) and the Type 502 *prestressed concrete multi-beam stringer or girder* (Figure 7).

All of those bridges were deck-girder structures with, for the most part, similar components. That simplified the field inspection process and allowed KTC to use students and researchers who did not have significant bridge expertise to conduct field evaluations.

The KYTC Bridge Inspection Report form uses the standard National Bridge Inventory (NBI) numeric 10-scale condition ratings from 0 to 9 with 0 indicating a failed condition and 9 indicating an excellent or like new condition (6). Higher rating numbers indicate better element conditions as shown in Table 2. Ratings are provided for major elements-deck, superstructure, substructure, retaining walls, channel/channel protection as well as identification of deck wearing surface type and condition, paint condition (if relevant), approach alignment, waterway adequacy, and water-affected elements of the substructure (from the splash zone down). Deck condition ratings include the structural condition, joints, drains, expansion devices, railings and lighting (and overall ratings). Superstructure condition ratings include stringers/girders/beams, floor beams, truss elements, structural member alignment, deflections/ vibrations under load and debris on members (and overall ratings). The substructure ratings include abutments/wing walls, piers/bents, alignment/settling, scour/erosion, debris on seats/cap and protection systems if present (and overall ratings). Some of those component ratings such as roadway alignment and water-affected items did not apply to the focus items identified by the Study Advisory Committee and are not of relevance to this study.

The KTC condition/distress rating system used to rate component conditions and pre-selected distress mechanisms employed a coarser scale (0-5 points) than the 10-point NBI scale. It was developed because KTC personnel conducting the field evaluations (typically students and technicians) lacked the special training and experience to conduct the KYTC NBIS inspections and provide comparable results to KYTC inspectors. On the KTC scale, a 0 rating is provided for the “Lowest Rating, Failed or Non-Existent.” A rating of 5 is used for components with the “Best Possible Rating, Excellent Condition or Like New.” While the two ratings systems are not entirely compatible, an approximate conversion is presented in Table 2 to allow relative scaling between them.

A component inspection/rating form was prepared by KTC researchers including those persons conducting the field evaluations. Besides providing component ratings, the inspection sheet was intended to identify the types of bridge components in place (e.g. embankment treatments, drain types, joint types, etc.), provide evaluations of components identified as being of interest by the Study Advisory Committee, and rate the components’ susceptibility to common problems/deterioration. Candidate inspectors were taken to 5 representative bridges where they rated and classified bridge components. After rating those bridges, they discussed the identification of bridge components and arrived at a consensus on the component ratings using the KTC rating scale. After this training, they were considered sufficiently trained to conduct the bridge inspections. On most site investigations, the KTC inspectors traveled in pairs providing the input of several persons in the rating process to make the ratings less subjective.

In consultation with Division of Maintenance officials, KTC researchers elected to inspect the 7 bridge types in 8 Central Kentucky counties (Anderson, Clark, Fayette, Franklin, Jessamine, Montgomery, Scott and Woodford). Thereafter as many of the targeted bridges were inspected as time permitted. Those counties had 375 of the 7 bridge types. Of those, 319 (85.1 %) were inspected. The totals and %ages for all types inspected by KTC are shown in Table 3. Overall, KTC researchers were able to inspect 5.78 % of all KYTC bridges in the 7 most common types, with the inspections ranging from 3.56 % for Type 505 bridges to 11.52 % for the Type 204 bridges. The results of those inspections and other KTC analyses are presented below.

KYTC Bridge Inspection Reports

In 1998, KTC obtained KYTC Bridge Inspection Reports for the 7 bridge types from 8 Central Kentucky counties. The dates of those inspections ranged from 1994 to 1997. Structural Inventory & Appraisal Forms were also obtained for most of the bridges. The condition ratings on these forms were placed on a spreadsheet grouped by bridge type, NBI structure identification, the county where a bridge was located, and its age. In a few instances, bridges contained multiple structure types (e.g. multi-span continuous, concrete and simple span steel). In those cases, the most predominant type of structure was used to classify the bridge (e.g. multi-span continuous concrete).

The average ages and average overall condition ratings for the decks, superstructures and substructures for all of the bridges inspected by both KYTC and KTC representing the 7 bridge types are provided in Table 4. As shown in Table 4 and Figures 8-10, the condition ratings for the different bridge types tended to decrease with the increasing average age of the bridge types. The average age of bridges ranged from 9.2 years for the Type 602 *prestressed concrete continuous multi-beam stringers or girders* to 48.2 years for the Type 302 *steel multi-beam stringer or girder*. The average overall deck condition rating varied from 6.41 for the Type 104 *concrete tee beam* to 7.56 for the Type 602 bridges. The average overall superstructure condition ratings varied from 6.35 for Type 302 bridges to 7.91 for Type 602 bridges. The average overall substructure condition ratings varied from 6.14 for Type 302 bridges to 7.88 for Type 602 bridges. Distributions of the condition ratings of the three principle bridge elements are shown in Figures 11-13.

Decks

The KYTC deck and deck component condition rating data from the NBI report forms for the bridges in this study are summarized in Tables 5 and 6. The lowest average condition ratings were for the joints, drains and lighting or utilities: those being in the *fair* to *good* ranges. The average deck structural condition and wearing surface ratings were in the *satisfactory* to *good* ranges.

About one-quarter of the Type 104 *concrete tee beam* bridges in this study had been blacktopped (paved over with plain asphalt). About one-half of those bridges had latex overlays. One bridge had an asphalt/membrane (also called waterproofing membrane) overlay and only about one-quarter had not been overlain (i.e. original decks). The oldest group (48.6 years avg.) had blacktopped decks and also had the lowest avg. overall deck condition rating (4.72). The latex overlain decks were nearly as old (42.7 years avg.) and rated almost as good in average overall deck condition (6.95) as the non-overlain decks (7.00) that were about the same age (45.6 years avg.). The available data indicated that the overlays were about 10 years old on average at the time of inspection and rating. Epoxy coated reinforcing steel had been used on one bridge with a latex overlay. None of the non-overlain decks had epoxy coated reinforcement. KYTC inspector comments on decks are provided in Table 7. They noted deck deterioration on about 29 % of the Type 104 bridges, deck cracking on another 29 %, delaminations and spalling on 15 % of the decks and potholing on 5 % of them. The most frequent comments by the KYTC inspectors on other deck issues related to joint deterioration and leaking affecting about 33 % of those bridges and curb/sidewalk spalling affecting another 8 %.

None of the Type 204 *concrete continuous tee beam* bridges in this study had been blacktopped. About two-thirds had decks with latex overlays and the remaining third was non-overlain. Oddly, the average age of bridges for both deck types was nearly identical (35.7 years and 35.8 years respectively for the overlain and non-overlain bridges). The average condition ratings were also similar (6.91. and 7.00 respectively for the overlain and non-overlain bridges). Available data indicated that the overlays were about 10 years old on average at the time of inspection and rating. One of the latex overlay bridges had epoxy coated reinforcing steel as did one non-overlain bridge. The KYTC inspectors commented on deck cracking being present on about 41 % of the Type 204 bridge decks, deck deterioration was mentioned on about 18 % of them and 4 % were said to possess potholes. Overlay deterioration, cracking and spalling were mentioned on about 19 % of the bridge decks. The KYTC inspectors also commented on deteriorated joints on 23 % of the bridges, curb/sidewalk spalling on 8 %, damaged railing on 8 %, and railing spalling on one bridge.

About one-quarter of the Type 302 *steel multi-beam stringer or girder* bridges in this study had been blacktopped. One-quarter of them had latex overlays and one bridge had an asphalt membrane deck. Slightly more than half of those bridges carried railways and did not have vehicle decks. There were no Type 302 bridges with non-overlain decks. The blacktopped decks were older than the latex overlays (52 years avg. and 35 years avg. respectively) and, as anticipated, they had lower average condition ratings (5.9 and 7.0 respectively). The one bridge deck with a sheet/asphalt membrane deck was 39 years old and had an overall deck condition rating of 5. The average age of the 20 railroad bridges was 52 years. The KYTC inspectors noted deck deterioration on 16 % of the Type 302 bridges, observing cracking on 5 % of the decks and overlay deterioration/ cracking/spalling on 8 % of them. They also noted that 24 % of the bridges had leaking joints.

Slightly over one-third of the Type 402 *steel continuous stringer or multi-beam stringer or girder* bridge decks in this study had latex overlays. The remaining two-thirds of those bridges had non-overlain decks. There were no Type 402 bridges involved in this study that had blacktopped or asphalt/membrane decks. The average age of the latex overlain decks was greater than the non-overlain ones (29.4 years and 21.5 years respectively). The average age of the latex overlays was about 11 years at the time of their inspection. The average overall deck condition ratings for both bridge types were identical (6.86). One-half of the non-overlain Type 402 bridge decks had black steel reinforcement and the remainder had epoxy coated reinforcement. The average age of the black steel reinforced decks was greater than the epoxy reinforced ones (27.6 years. and 15.6 years respectively) and the average overall deck condition ratings were lower (6.2 and 7.6 respectively). KYTC inspectors noted deck cracking on 48 % of the decks and potholing in 14 % of them. They also commented on deteriorating joints on 48 % of the bridges and curb/sidewalk cracking on 19 % of them.

Nearly all of the Type 502 *prestressed concrete multi-beam stringer or girder* bridges had non-overlain decks. Only one deck of that bridge type possessed a sheet membrane/asphalt deck. The average age of the non-overlain bridges was only 10.1 years and their average overall deck condition rating was 7.67. All of those bridges had decks with epoxy coated reinforcing steel. The lone Type 502 bridge with a membrane deck was 29 years old having an overall deck condition rating of 4.00. The KYTC inspectors noted deck cracking in about 23 % of those bridges and leaking joints in 9 % of them.

About one-third of the Type 505 *prestressed concrete, multiple box beam or girder* bridges in this study had blacktopped decks. The remaining two-thirds of those bridges had non-overlain decks. There were no membrane or latex overlays used on this type of bridge. The blacktopped bridges were older than the non-overlain bridges (27.5 years and 19.6 years respectively) and had lower average overall condition ratings (6.72 and 7.67 respectively). NBI data indicated that black reinforcing steel was used in 6 of the non-overlain bridge decks and epoxy coated reinforcing steel was used in 10 others. The black reinforcing steel decks were older than the epoxy coated ones (24.8 years and 13.6 years respectively) and had lower overall average condition ratings (6.57 and 7.60 respectively). The KYTC inspectors noted deck cracking on 6 % of the bridges and deck spalling on one bridge. They also noted damaged deck railings on 9 % of the bridges.

Almost all of the Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges in this study had non-overlain decks. Those bridges had an average age of 8.9 years and an average overall rating of 7.57. One Type 602 bridge had a latex overlay. It was 18 years old and had a rating of 7.00. Two of the non-overlain bridges had black reinforcing steel and 30 of the others had epoxy coated reinforcing steel. The two bridges with black steel were older than the ones with epoxy coated rebar (17.0 years and 8.3 years respectively) but both had similar average overall deck ratings (7.50 and 7.60 respectively). The KYTC inspectors noted cracking on 31 % of the bridge decks and spalling and potholing each on one bridge. They commented on deteriorating/ leaking joints on 16 % of the bridges.

Superstructures

KYTC component average condition ratings for superstructures of the 7 bridge types are provided in Table 8. The condition of the stringers/beams/girders comprised a significant portion of the composite ratings for the superstructures. All the average ratings were in the *fair* to *good* range.

KYTC inspector comments for the bridge superstructures are provided in Table 9. For the Type 104 *concrete tee beam* bridges, the most frequent comments related to girder deterioration (12 % of the bridges), traffic damage (6 %) and girder cracking (7 %). For Type 204 *concrete continuous tee beam* bridges, most comments related to girder spalling (8 %) and traffic damage (7 %). For the Type 302 *steel multi-beam stringer or girder* bridges, inspectors frequently noted a need for bridge painting (49 %), bearing corrosion (27 %), and traffic damage to girders (19 %). For the Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges, the inspectors commented on the need for bridge painting (33 %) and bearing corrosion (48 %). For the Type 502 *prestressed concrete multi-beam stringer or girder* bridges, the major inspector comments related to girder spalling (9 %). For the Type 505 *prestressed concrete, multiple box beam or girder* bridges, KYTC inspectors commented on girder spalling (16 %) and leaking between the boxes (13 %). For the Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges, KYTC inspectors also noted girder staining (9 %), girder spalling (13 %), and girder cracking (6 %).

Steel Coatings/Painting

Most of the coatings rated by inspectors were on Type 302 and 402 bridges as shown in Table 10. Apparently one Type 204 *concrete continuous tee beam* bridge contained a steel span. Thirty one Type 302 *steel multi-beam stringer or girder* bridges had average coating condition ratings of 5.03 or *fair*. Twenty one of the Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges had coatings rated by the KYTC inspectors. The average condition rating for those coatings was 6.9. Data indicated that most of the bridge coatings had been applied between 1969 and 1994.

Substructures

KYTC average component condition ratings for substructures of the 7 bridge types are provided in Table 11. The average condition of the bridge type/substructure components ranged from *fair* to *good* except for scour protection systems for the Type 204 bridges which had an average rating of *poor* for 2 bridges (the ratings for the rest of the bridges in that type were *not applicable*).

KYTC inspector comments for the bridge substructures (piers/abutments/wing walls) are provided in Table 12. For the Type 104 *concrete tee beam* bridges, inspectors noted deterioration (32 %), cracking (17 %), spalling (19 %) and staining (9 %). For Type 204 *concrete continuous tee beam* bridges, inspectors commented primarily on deterioration (11 %), cracking (19 %) and spalling (18 %). They also noted settling/abutment movement (8 %) and girders jammed into abutments (4 %). For the Type 302 *steel multi-beam stringer or girder* bridges, KYTC inspectors noted cracking (5 %), spalling (24 %) and pier/abutment/wing wall staining (8 %). For the Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges, KYTC inspectors primarily noted cracking (24 %) and spalling (14 %). For the Type 502 *prestressed concrete multi-beam stringer or girder* bridges, KYTC inspectors mainly commented on cracking (23 %) and spalling (9 %). For the Type 505 *prestressed concrete, multiple box beam or girder* bridges, KYTC inspectors noted few problems. For the Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges, KYTC inspectors mostly noted cracking (16 %) and spalling (13 %).

Bridge Inspector Comments

KYTC inspector comments on the NBI forms related to bridge maintenance and other conditions that needed to be addressed are provided in Table 13. Dirty decks (indicating a need for deck cleaning) were noted for every bridge type, with frequency of comments ranging from 5 % for Type 502 *prestressed concrete multi-beam stringer or girder* bridges to 14 % for Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges. Clogged drains were also noted for all bridge types except the Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges. Exposed rebar was also noted for all bridge types except the Type 602, ranging from 5 % for the Type 502 *prestressed concrete multi-beam stringer or girder* bridges to 20 % for the Type 104 *concrete tee beam* bridges. Other conditions requiring attention that were frequently noted for most bridge types included rough approaches/impacts, brush around bridges, and erosion at the abutments/other locations. Other minor issues included failed masonry coatings, deterioration of limestone blocks, pigeon dropping build-up, and graffiti.

KYTC Data From 2004

In Spring 2004, KTC researchers conducted a review of more recent KYTC NBI data on the 319 bridges inspected by KTC in 1998 and also obtained Structure Inventory & Appraisal forms from the KYTC District 5 Office in Louisville on bridges in Franklin County and the KYTC District 7 Office in Lexington for bridges in Anderson, Clark, Fayette, Jessamine, Montgomery, Scott, and Woodford counties.

Bridges Removed from Service/Rehabilitated

Information taken from the District NBI files in 2004 indicated that some bridges inspected by KTC in 1998 had subsequently been removed from service. Bridge removals accounted for 28 of the original 319 bridges inspected—a removal rate of 8.7 %. Those bridges were replaced/closed due to structural and functional deficiencies, roadway improvements, and rail system closures. Bridges removed from service included: 7 Type 104 *concrete tee beam* bridges, 9 Type 204 *concrete continuous tee beam* bridges, 8 Type 302 *steel multi-beam stringer or girder* bridges, 3 Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges, and one Type 505 *prestressed concrete, multiple box beam or girder* bridge. No Type 502 *prestressed concrete multi-beam stringer or girder* bridges or Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges had been removed from service.

The District records also indicated that a number of the previously inspected bridges had subsequently been rehabilitated. Those included 8 Type 104 bridges, 2 Type 204 bridges, and one Type 505 bridge. Several bridges had overlays or partial deck replacements including: 7 latex overlays, one asphalt blacktopping and one PCC partial re-decking on Type 104 bridges; 3 latex overlays on Type 204 bridges; one latex overlay on a Type 302 bridge; and one asphalt blacktopping on a Type 505 bridge.

Changes in Condition Ratings of Bridge Elements/Deck Components

A comparison of KYTC condition ratings was made for the previously inspected bridges remaining in service to determine changes (decreases) over the period between the most recent available condition ratings (2001-03) and those initially provided to KTC (1994-97). That data is presented in Table 14 (for major bridge elements) and Table 15 (for specific deck components). As shown in Table 14, the average conditions ratings for the major bridge elements (decks, superstructures, and substructures) all decreased over the 6-8 year intervals between those KYTC inspections.

The magnitude of those decreases varied. For decks, the Type 502 *prestressed concrete multi-beam stringer or girder* bridges had the greatest decrease in average condition ratings (1.18) while the Type 302 *steel multi-beam stringer or girder* bridges had the least (0.55). The average decrease in deck condition ratings for the 7 bridge types was 0.83. For superstructures, the Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges had the greatest decrease (1.15) while the Type 302 bridges had the least (0.31). The average decrease in superstructure condition ratings for the 7 bridge types was 0.76. For substructures, the Type 602 bridges had the greatest decrease (1.21) while the Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges had the least (0.56.). The average decrease in substructure condition ratings for the 7 bridge types was 0.86.

Changes in the condition ratings for deck elements (wearing surfaces, joints and expansion devices) were also reviewed as KTC researchers believed that they might be subject to significant deterioration. For deck wearing surfaces, the Type 502 bridges had the greatest decrease in average condition ratings (1.18) and the Type 104 *concrete tee beam* bridges had the least (0.80). The average decrease in deck wearing surface condition ratings for the 7 bridge types was 1.04. Deck joints on the Type 602 bridges had the greatest decrease in average condition ratings (1.28) and the Type 104 *concrete tee beam* bridges had a slight increase of (0.04). The average decrease in deck joint condition ratings for the 7 bridge types was 0.51. Expansion devices on the Type 402 bridges had the greatest decrease in average condition ratings (1.81) and the Type 104 *concrete tee beam* bridges had the lowest decrease (0.25). Expansion devices were not applicable for the Type 505 *prestressed concrete, multiple box beam or girder* bridges. The average decrease in expansion device condition ratings for the 6 bridge types that employed them was 0.84.

General Information for the 7 Bridge Types

During this KTC data gathering at the KYTC District offices, additional bridge information was obtained from the Structure Inventory & Appraisal forms. That information related to the bridges that were inspected by KTC in 1998 that remained in service in 2004. Additional information was obtained from the KYTC Central Office. That information would provide insights about future maintenance and replacement options for those structures.

The 92 Type 104 *concrete tee beam* bridges remaining in the KYTC inventory had an average age of 44.6 years in 1999. For sufficiency ratings, Type 104 bridges had the following distributions: sufficiency ratings less than 50 (one bridge), sufficiency ratings between 50-to-80 (55 bridges) and sufficiency ratings greater than 80 (36 bridges). Of the Type 104 bridges, 5 were rated as structurally deficient, 14 were rated functionally obsolete and 51 had low capacity points. Only 4 of those bridges were load posted. The Type 104 bridges were of the following service types: highway-waterway (58 bridges), highway-highway (18 bridges), interstate-highway (8 bridges), highway-railroad-waterway (5 bridges), highway-railroad (2 bridges), and highway-highway-waterway (one bridge). The types of routes carried for the Type 104 bridges were distributed as follows: interstate (11 bridges), parkway (12 bridges), state primary (18 bridges), state secondary (28 bridges), rural secondary (27 bridges), and county or city streets (one bridge). Current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 100 to 35,000 vehicles per day for those bridges.

The 62 Type 204 *concrete continuous tee beam* bridges remaining in the KYTC inventory had an average age of 35.8 years in 1999. For sufficiency ratings, Type 204 bridges had 28 bridges with sufficiency ratings between 50-to-80 and 34 bridges with sufficiency ratings greater than 80. Of the Type 204 bridges, 2 were rated functionally obsolete and 22 had low capacity points. None of those bridges were load posted. The Type 204 bridges were of the following service types: highway-waterway (4 bridges), highway-highway (38 bridges), highway-interstate (5 bridges), highway-railroad-waterway (one bridge), highway-railroad (4 bridges), highway-highway-waterway (6 bridges) and interstate-waterway (4 bridges). The types of routes carried for the Type 204 bridges were distributed as follows: interstate (17 bridges), parkway (8 bridges), state primary (12 bridges), state secondary (16 bridges), unclassified (7 bridges) and rural secondary (2 bridges). As previously noted current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 200 to 37,700 vehicles per day for those bridges.

The 29 Type 302 *steel multi-beam stringer or girder* bridges remaining in the KYTC inventory had an average age of 45.1 years in 1999. For the Type 302 bridges, limited sufficiency ratings were available. Those that were provided had the following distributions: sufficiency ratings less than 50 (4 bridges), sufficiency ratings between 50-to-80 (7 bridges) and sufficiency ratings greater than 80 (2 bridges). Of the Type 302 bridges, one was rated structurally deficient and 20 had low capacity points. Two of those bridges were load posted. The Type 302 bridges were of the following service types: highway-waterway (5 bridges), highway-highway (8 bridges), highway-interstate (2 bridges), railroad-highway (16 bridges) and railroad-highway-waterway (one bridge). The types of routes carried for the Type 302 bridges were distributed as follows: interstate (6 bridges), parkway (2 bridges), state primary (10 bridges), state secondary (5 bridges), unclassified (one bridge) and rural secondary (5 bridges). As previously noted, current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 200 to 39,300 vehicles per day for those bridges.

The 20 Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges remaining in the KYTC inventory had an average age of 25.2 years in 1999. Sufficiency ratings were not available for 3 Type 402 bridges. For the remainder, 5 had sufficiency ratings between 50-to-80 and 12 had sufficiency ratings greater than 80. None of the Type 402 bridges were rated as structurally deficient or functionally obsolete, but 13 had low capacity points. None of those bridges were load posted. The Type 402 bridges were of the following service types: highway-waterway (2 bridges), highway-highway (10 bridges), interstate-highway (2 bridges), highway-railroad (4 bridges), and interstate-interstate (2 bridges). The types of routes carried for the Type 402 bridges were distributed as follows: interstate (10 bridges), state primary (8 bridges) and state secondary (2 bridges). Current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 100 to 36,300 vehicles per day for those bridges.

All 22 Type 502 *prestressed concrete multi-beam stringer or girder* bridges inspected by KTC researchers in 1998 remained in the KYTC inventory in 2004. They had an average age of 10.7 years in 1999. Type 502 bridges had one bridge with a sufficiency rating between 50-to-80 and 23 bridges with sufficiency ratings greater than 80. None were rated as structurally deficient, 2 were rated functionally obsolete and 6 had low capacity points. None of those bridges were load posted. The Type 502 bridges were of the following service types: highway-waterway (16 bridges), interstate-highway (2 bridges), highway-railroad (2 bridges), and pedestrian-highway (2 bridges). The types of routes carried for the Type 502 bridges were distributed as follows: interstate (2 bridges), state primary (5 bridges), state secondary (13 bridges) and rural secondary (2 bridges). Current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 50 to 34,300 vehicles per day for the vehicular bridges in that category.

The 32 Type 505 *prestressed concrete, multiple box beam or girder* bridges remaining in the KYTC inventory had an average age of 21.6 years in 1999. Sufficiency ratings were not available for all bridges. Available data indicated that 13 Type 505 bridges had sufficiency ratings between 50-to-80 and 16 bridges had sufficiency ratings greater than 80. Of the Type 505 bridges, 2 were rated functionally obsolete and 17 had low capacity points. None of those bridges were load posted. The Type 505 bridges were of the following service types: highway-waterway (31 bridges) and highway-railroad (1 bridge). The types of routes carried for the Type 505 bridges were distributed as follows: state primary (2 bridges), state secondary (5 bridges), unclassified (2 bridges) and rural secondary (23 bridges). Current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 100 to 3,500 vehicles per day for the bridges in that category.

All Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges inspected by KTC researchers in 1998 remained in the KYTC inventory. They had an average age of 9.2 years in 1999. For sufficiency ratings, Type 602 bridges had 2 bridges with sufficiency ratings between 50-to-80 and 32 bridges with sufficiency ratings greater than 80. None of the Type 602 bridges were rated as structurally deficient and none had low capacity points. Nine were rated functionally obsolete. None of those bridges were load posted. The Type 602 bridges were of the following service types: highway-waterway (10 bridges), highway-highway (3 bridges), interstate-highway (4 bridges), interstate-waterway (6 bridges), interstate-railroad (2 bridges), highway-railroad (7 bridges), and highway-interstate (2 bridges). The types of routes carried for the Type 602 bridges were distributed as follows: interstate (12 bridges), state primary (10 bridges), state secondary (8 bridges), unclassified (2 bridges) and rural secondary (2 bridges). Current average daily traffic data was not available, but the data that existed indicated a wide variance in traffic ranging from 300 to 52,500 vehicles per day for those bridges.

District 7 General Maintenance Forms

District 7 employs documents termed "General Maintenance Forms" that allow KYTC inspectors to indicate bridge maintenance needs to district bridge foremen. The needs indicated on the forms comprise part of their bridge repair schedule for the year. District maintenance engineers and maintenance foremen that also get the forms address some of the needs indicated on those documents. Once these forms are completed, KYTC inspectors are not involved further in their implementation. KTC researchers reviewed the most current General Maintenance Forms for the bridges KTC inspected in 1998 (that remained in service through spring 2004). That group of bridges included: 82 Type 104 *concrete tee beam* bridges, 57 Type 204 *concrete continuous tee beam* bridges, 28 Type 302 *steel multi-beam stringer or girder* bridges, 14 Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges, 21 Type 502 *prestressed concrete multi-beam stringer or girder* bridges, 29 Type 505 *prestressed concrete, multiple box beam or girder* bridges and 30 Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges. District 5 did not employ General Maintenance Forms. Therefore, the maintenance needs for bridges from that District (Franklin County) could not be evaluated. Table 16 provides a listing of bridge maintenance (and other) needs for structures for each of the 7 bridge types in District 7.

KTC commentary on the needs identified in the General Maintenance Forms is contained in "A Commentary on KYTC Options for Bridge Management" in APPENDIX 1.

KTC Inspection Results

The KTC bridge inspections addressed the condition of components/features of interest to the Study Advisory Committee and focused on aspects of bridge component performance. To address the latter issue, the KTC inspections considered not only component performance, but the types of components involved and the types of distress (and severity) impacting them. Also, some components had several functions and were exposed to different forms of distress. Therefore, their performance could not be evaluated by a single condition rating. As previously stated, the results of the KTC inspections were not entirely analogous to the KYTC condition ratings. While comparative ratings between the KYTC and KTC might be possible in some instances (Table 2), they are not encouraged. It is recommended that the KTC data stand alone for assessing the relative performance of bridge components within each of the 7 bridge types.

KTC inspectors were fairly thorough in correctly identifying the bridge components. For various reasons (e.g. component access, inability to judge a particular component's condition, etc.), they did not consistently provide ratings on all components of some bridges. Researchers audited all the KTC inspection report forms and bridge pictures to make necessary corrections for component identification/ratings and provide missing data where possible, but not all ratings were provided. In most cases, sufficient information/ratings were furnished to determine the performance for each bridge type and category of component.

For some bridge types, particular component types/designs were used to the exclusion of others. Alternative components types were only employed when those bridges that had been modified or rehabilitated. This tended to obscure differences in performance between component types. The findings indicate that, for the most part, the performance of the various types of component designs (e.g.. sliding plates or compression seals) within each bridge component type (e.g. deck joints) are not as critical as the overall performance of the general component type.

Decks

KTC ratings for the bridge decks, bridge deck components, their performance and severity of various types of distress are provided in Tables 17-21. As shown in Table 17, the overall average deck condition for the 7 bridge types rated *good* to *very good* as did the overall ride quality. The average distress ratings of the decks due to concrete spalling or cracking were also rated *good*. Concrete deck finishes varied in overall quality. Tyned finishes rated significantly higher than broomed finishes which were mostly rated *poor* to *fair*. That was due to the common erosion of the broomed finishes in wheel paths. The performance of the epoxy sand seals was also rated as *poor* or *non-existent* for all bridge types (though epoxy sand seals may not have been widely applied on all bridges due to their design or to the bridges pre-dating the use of that feature).

Most bridges inspected had end-treatments. The percentages of those having end-treatments are: Type 104 (77.8 %), Type 204 (93.0 %), Type 302 (59.8 % of roadway bridges), Type 402 (100.0 %), Type 502 (86.4 %), Type 505 (72.9 %) and Type 602 (97.1 %). In some cases, bridges employed guardrails for barrier walls. Some of the newer bridges had buffered guardrail end pieces that were not rated as being an effective end treatment due to their close proximity to the end of the bridge. Protective end-treatments on barrier walls commonly consisted of some galvanized steel guardrail design with an end treatment similar to those used by KYTC on conventional guardrails with the other end tied to the concrete barrier wall. As shown in Table 18, the average distress of those guardrails due to corrosion and vehicle impact were rated from *good* to *excellent*. The galvanizing was effective in protecting the steel guardrails from corrosion and most crash-damaged end treatments had been effectively repaired/replaced. The overall barrier wall quality rated from *good* to *very good*. Very few had sustained significant crash damage. Many of the barrier walls were made from reinforced concrete. Most had not been significantly damaged by either spalling or cracking. Bridge types employing galvanized rails as barriers (either with galvanized steel posts or backed by vertical concrete walls), had guardrails with *very good* condition ratings. On vertical barrier walls with safety curbs, the aluminum top rail average condition ratings ranged from *good* to *like new*.

Table 19 provides condition/distress ratings for bridge approaches. Approach slabs were not used with the Type 104 *concrete tee beam* bridges and Type 204 *concrete continuous tee beam* bridges. Type 302 *steel multi-beam stringer or girder* bridges and Type 505 *prestressed concrete, multiple box beam or girder* bridges had only one approach slab each. Approach slabs were used more commonly on Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges (6 bridges), Type 502 *prestressed concrete multi-beam stringer or girder* bridges (3 bridges), and Type 602 *prestressed concrete continuous multi-beam stringers or girders* bridges (6 bridges). For those bridge types, approach slab susceptibility to distress (settlement, cracking and heaving) was low with: average settlement ratings ranging from above *good* to *very good*, most average cracking ratings being *very good* and most average slab heaving ratings rating above *good*. For conventional paved approaches, the patching/wedging rated from *fair* to *very good*. The approach (roadway) sag ratings ranged from *fair* to *very good*. There approach slopes rated from *good* to *very good*. Approach erosion ratings ranged from *fair* to *good*.

Table 20 provides the condition/distress ratings for bridge drains and joints. The average overall drain condition ratings ranged from *very good* to *excellent*. That indicates that they had received little service-related deterioration/damage. The drain clogging distress rating ranged from *fair* to *very good*. The overall joint condition ratings ranged from *fair* to *very good* with most being rated in the *fair* to *good* condition. The joint ride quality performance ratings ranged from *good* to *very good* with most being *very good*. The joint average ratings for watertight performance for the Type 104, Type 204 and Type 302 bridges were rated *fair*, while the same ratings for the Type 402, 502, 505 and 602 bridges was generally higher being rated *good*. Distress ratings for joint material spalling ranged from *fair* to *very good*. Joint material tearing/detaching distress ratings ranged from *fair* to *very good*. Debris build-up at joint distress ratings ranged from *fair* to *good*. Loose/broken joint distress ratings varied from *poor* to *very good*.

Table 21 provides the bearing (expansion device) average overall condition and distress ratings. No average overall bearing condition ratings were provided for the Type 502 bridges. Most of those bridges either employed integral abutments or had bearings that could not be accessed for proper inspection by KTC researchers. Condition ratings for the other bridge types were generally *fair* to *excellent* with most being rated *very good*. Excessive tilt distress ratings were *fair* for the Type 104 bridges, and ranged from *good* to *excellent* for the other bridge types. Pad-sliding-off-bearing-plate distress ranged from *good* to *excellent* indicating few problems of that nature. Deformed-bearing-pad distress ratings ranged from *good* to *excellent* also indicating few problems with that issue. Bearing corrosion ratings ranged from *fair* to *excellent*.

One shortcoming of this study is that good traffic data was not available for many of these bridges. That includes both historic and current traffic volumes (and probably distributions of vehicle types). In the future, that data would be useful for predicting deck degradation rates, future maintenance needs and deck service lives.

Superstructures

Beam/girder overall average condition ratings and distress ratings are provided in Table 22. The average overall condition of the beams and girders ranged from *good* to *very good* for the bridge types. Vehicle impact distress was noted on only three bridges and had very little effect on beam conditions. Vandalism distress was also noted on the beams three bridges but had little effect on beam conditions. Corrosion distress ratings were provided for the Type 304 and Type 402 bridges that had steel beams and girders (*good* and *very good* respectively). Average concrete-staining distress ratings for bridge with concrete beams and girders ranged from *fair* to *very good*. Average concrete-damage distress ratings for those bridges were *very good* indicating that was not a widespread problem issue.

Substructures

Table 23 provides the average distress ratings for embankments and the condition/distress ratings for bridge abutments. The average embankment erosion ratings ranged from *fair* to *very good*. Embankment settlement distress ratings were provided only for the Type 104 and Type 402 bridges. Those ratings were *very good* to *excellent* indicating that was not a problem issue. Average abutment settlement ratings were provided for the Type 104, Type 204 and Type 505 bridges. Again, these ratings were high ranging from *very good* to *excellent* indicating that that was not a problem. Average abutment overall condition ratings varied from *good* to *very good*. For abutment cracking, the ratings ranged from *fair* to *good*. For abutment (concrete) spalling, the condition ratings ranged from *fair* to *very good*. For abutment tilting (moving), most of the average ratings ranged from *good* to *excellent*. For abutment stain (from joint leaking) the abutments varied from *fair* to *good*.

Pier average overall condition and distress ratings are provided in Table 24. The average overall condition ratings varied from *fai*r to *excellent*. Pier (concrete) spalling distress ratings varied from *fair* to *very good*. Pier splitting/cracking ratings varied from *fair* to *excellent*. Rusting/rust spot distress ratings ranged from *fair* to *like new*. Pier staining (from joint leaking) ranged from *fair* to *very good*. Vehicle collision damage to piers ranged from *fair* to *very good*.

Bridge Aesthetics

Bridge average overall aesthetics and distress are provided in Table 25. The average overall aesthetics varied from *fair* to *very good*. Graffiti ratings varied from *fair* to *good*. The staining distress rating varied *poor* to *good*. Vehicle damage distress was only noted on Type 104, Type 204 and Type 302 bridges ranging from *fair* to *good*. Debris distress ranged from *poor* to *good*. Vegetation distress ranged from *fair* to *good*. Aesthetic cracking distress ratings varied from *poor* to *good*. Aesthetic distress ratings due to repair appearance (other than deck patching) varied from *fair* to *good*. Aesthetic distress ratings due to deck spalling/patching ranged from *poor* to *very good*.

Bridge Component Performance

The performance of specific bridge component types/designs is presented in Tables 26-33 including barrier walls, drains, deck joints, expansion devices, embankments, abutments, piers, and stay-in-place forms. Those tables indicate the frequency that specific component types were encountered on the 7 bridge types and their relative performance as measured by their condition ratings. As previously noted, the KTC condition rating data is not as complete as desired. Most of the major components and types have been accounted for in the tables. In some cases, components/types were not present or were not commonly encountered for a given bridge type due their design (e.g. deck drain and joints). Some component designs/types were generally associated with specific bridge types such as the use of poured asphalt joints with Type 104 *concrete tee beam* bridges.

Data not tabularized included ratings for armored edges versus non-armored edges, masonry coatings and bridge paint. The condition ratings for joints/deck with armored edges and non-armored edges were indistinguishable and no significant difference could be discerned. Concrete on non-armored edges was subject to spalling and D-cracking and similar damage was observed in deck concrete adjacent to armored edges which were also susceptible to snowplow damage and coming loose under heavy traffic (Figures 14 and 15). The KTC average condition ratings for the masonry coatings ranged from 3.25 (*fair*) for Type 104 *concrete tee beam* bridges to 4.53 (*very good*) for Type 204 *concrete continuous tee beam* bridges. The average paint (coatings) condition ratings for the Type 302 *steel multi-beam stringer or girder* bridges and Type 402 *steel continuous stringer or multi-beam stringer or girder* bridges were 4.14 and 4.25 (*very good*) respectively.

CONCLUSIONS

Study Advisory Committee Concerns

The KTC research findings relative to the 12 bridge components/treatments of interest to the Study Advisory Committee are discussed below.

1. Expansion/deck joints

The bridges in this study possessed a variety of deck joints/seals including the semi-open joints (sliding plates) and closed joints including poured-in-place asphalt, open compression seals, strip seals, poured-in-place silicon, segmental (or plank) seals, and modular joints. Both KTC and KYTC data obtained in this study have indicated that joint performance and durability pose problems. In this study and in the course of other work on bridges, the damaging effects of joint leakage were frequently observed (Figure 16). Joint leakage causes problems such as steel corrosion and concrete cracking/spalling on underlying superstructure and substructure elements (Figures 17 and 18).

Open deck joints such as finger dams and semi-closed joints such as sliding plates can allow water and de-icing salts to deposit upon superstructure and substructure elements causing significant deterioration. Closed joints have been employed for some 40-50 years as a means of accommodating structure movement while preventing water, deicing salts and debris from falling onto underlying superstructure and substructure elements. Originally, poured asphalt was widely used as a joint seal. However, as the KTC inspection data showed, poured asphalt does not provide a good watertight seal though it otherwise provides good durability. More effective alternatives with better watertight properties have been employed including compression seals, strip seals, asphalt plug seal, segmental and modular joints.

Most of the closed joints inspected on the 7 bridge types were open (cell) compression seals (Figure 19). KTC researchers observed a few strip seals and found they were performing well. That conforms to survey responses from the Minnesota, Illinois, and New Jersey DOTs in the NCHRP synthesis report on deck joints (7). Newer joint types include poured silicon, closed (cell) compression seals, and asphalt plug joints. Poured silicon joints are becoming more popular and a few were inspected as part of this study (Figure 20). KTC researchers are unaware of the use of closed compression seals on KYTC bridges. Asphalt plug joints have been used experimentally by KYTC, but were not involved in this study. The segmental joints inspected in this study were intact and performing *fair* to *good* (Figure 21). They had good ride quality. However, some rubber faces on the joints had received slight snowplow damage and most were not watertight. The modular joints encountered in this study were not rated by the KTC researchers. However, they were observed to be intact and appeared to be in good overall condition. A previous study indicated that segmental joints were susceptible to component failure, snow scraper damage, and leaking as were some early modular joints (8).

Modular joints were used on an experimental basis by KYTC from 1972-1981. Some of those early joints did not perform well requiring their replacement. In several cases, unsuitable applications may have contributed to their failure, but for the most part, most of the problems encountered were due to joint design inadequacies. In 1998, KTC researchers inspected paint work on the I-64 Riverside Parkway in Louisville. The Riverside Parkway project contained both modular joints and finger dams with rigid troughs (Figure 22). The modular joints that were inspected performed significantly better. The paint was in much better condition under the modular joints having only minor rust staining and no signs of beam corrosion (Figure 23). The modular joints were quiet under traffic indicating that they were probably intact. Several modular joints observed by KTC researchers on the U.S. 25 and I-471 bridges over the Ohio River at Covington and Newport in conjunction with paint-related work in 2000 and 2003 respectively. The joints were found to be quiet under traffic and joints on the U.S. 25 did not appear to be leaking (Figure 24). Some water leakage and corrosion on the floor system was observed under a large modular joint on the South end of the Northbound I-471 structure. However, the joint was otherwise intact.

Closed joints may last 10 years or more, but they can lose their watertight capability shortly after they are placed. Both the KYTC and KTC data indicate shortfalls in the watertight performance of closed deck joints. In observing many bridges around Kentucky and noting leakage stains on piers and abutments, it has become obvious to KTC researchers that current KYTC maintenance of closed joints is usually limited to replacing seals that have experienced severe mechanical damage or total failure (Figure 25). Some state highway agencies require leak tests on newly placed closed joints, and others don’t. Untested joints may be improperly constructed and begin to leak as soon as they are put in operation. Debris build-up in joint openings can result in traffic pushing the seals downward dislodging them and rendering them non-functional (Figures 26 & 27). Flexible joint seals are also subject to other forms of environmental degradation and traffic damage. Some transportation agencies have reported that compression seals lose their resilience over time and can cause problems, especially in applications where large joint movement is required. In some instances, KTC researchers have encountered joints that were completely closed crushing the compression seals. Those problems are probably caused by abutment movement or possibly deck creep.

With compression seals and poured joint materials like silicon, a range of deck edge preparation methods can be accommodated (armored and unarmored edges). However, strip seals are proprietary and are designed to fit special steel edge treatments. Once that edge treatment is installed, the replacement seals must be purchased from the same manufacturer and be subject to his cost and delivery constraints.

A problem area for deck joints appears to be the transition from the deck to the barrier wall (upturn). The design of those transition points appears to be prone to seal leakage. Oftentimes, the joint design consists of bending a compression seal upward at the barrier wall. On Type 104 bridges, the joint is usually poured asphalt in the deck with no joint closure on the barrier walls. This allows water leakage onto piers and abutments. Those are sites of pier cap reinforcing steel corrosion and concrete cracking and spalling (Figure 28).

Evaluation of joint performance data indicated that armored edges did not have a significant effect on joint performance. Newer closed joint designs incorporate the use of deck blockouts at the joints where a partial depth cutout is made in the deck ends and the Portland concrete is replaced with a polymer concrete. That feature is now widely used and is apparently performed well around the country.

2. Barrier wall joints

Barrier wall joints are intended to act as starter sites for cracking similar to the joints in concrete sidewalks. Typically, those joints are located in the negative moment areas on continuous deck girder bridges (concrete and steel). KTC researchers observed bridge barrier walls of various designs including the vertical walls with aluminum top rails and the New Jersey barrier design. In many cases, KTC researchers observed barrier walls containing vertical through-thickness cracks not only at the joints, but also a few feet from them (Figure 29). In some cases, extensive barrier wall cracking was observed from the joints (Figure 30). The cracks can be readily detected from a distance due to white efflorescence stains emanating from them.

Havens *et al* addressed the issue of thermally induced cracking in reinforced concrete pavement (9). They considered the strengths of steel in compression, concrete in tension, the relative areas of both materials in reinforced concrete structures, differences in thermal expansion and temperature shifts in the reinforced concrete. They concluded that some cracking in reinforced concrete structures could be attributed to differences in thermal expansion between the two materials. They determined that some reinforced concrete could crack at intervals of between approximately 2-1/2 to 4 feet due to thermal effects. In some cases, that type of cracking has been observed at locations where no other phenomena could explain it. New Jersey barriers usually possess more cracks (and more prominent cracks) than the old-style vertical wall/aluminum barrier type. Some of those earlier designs have joints spaced at 15- 20 ft. intervals.

3. Epoxy sand slurries

The epoxy sand slurries used in bridge deck gutter lines did not perform well. KTC data showed that they rated from *failed* to *poor* for the 7 bridge types (Figure 31).

4. Concrete surface coatings

Textured masonry coatings have been used on Kentucky bridges since 1970 when they replaced rubbed concrete as the standard finish on concrete structures. Those coatings hide minor concrete surface blemishes well and are relatively easy to apply. In the past several years, concrete tints (coatings that etch the cement) have begun to compete with masonry coatings. KTC inspections generally rated masonry coatings *good*. However, those coatings have several previously noted disadvantages: 1) they are not protective to the concrete; 2) they are readily damaged; and 3) they cannot be aesthetically repaired (10). Concrete tints have been used on bridge concrete for aesthetic purposes. They do not appear to be durable (Figure 32).

5. Bearings

KTC data indicated few issues with bearings. The three bearing types observed- rockers, sliding plates, and bearing pads were all rated from *good*-to-*excellent*. The only problems involved rockers on a few bridges that probably needed to be reset due to excessive tilt or corroded rockers that needed to be painted (Figure 33).

6. Approach slabs

Approach slabs were not a common feature on the bridges inspected by KTC researchers being encountered on 21 of 319 bridges. The data provided in Table 19 indicates that the approach slabs were performing as well as conventional approaches with the exclusion of moderate cracking noted on one Type 204 bridge (Figure 34). Approach slabs contributed to the overall ride quality over the bridge where they were employed. Except for one bridge where the ride quality was rated *fair*, the ride quality on the other bridges with approach slabs were all rated from *very good* to *excellent*.

7. Deck overlays

KTC NBI data on the relative performance of bridge decks contained in Table 10 indicated that the latex deck overlays employed by KTC are performing nearly as well as non-overlain bridge decks, though the total deck ages of both types is generally similar. Over 10 % of bridge decks involved in this study were blacktopped, but apparently they did not incorporate the use of membranes to protect the underlying deck concrete. With blacktopping, contaminants and moisture collect at the concrete-asphalt interface and accelerate deterioration of the underlying concrete deck. Conventional blacktopping is usually employed over severely deteriorated concrete decks to provide a temporary wearing surface prior to removing a deck (or bridge). If greater durability is sought, membranes (sheeting or liquid applied) are employed. Only three membranes were noted on the NBI forms (less than 1 % of the bridges inspected).

KYTC has received good service from latex overlays (and a few low-slump overlays). It was a pioneer in the use of latex mortars before switching to latex cements in the 1970s. For many maintenance applications, latex overlays remain a good option (Figure 35). Other transportation agencies have also employed microsilica overlays successfully. For a brief period in the 1970s, prior to the introduction of epoxy-coated reinforcing steel, KYTC used both membranes and overlays on new decks.

8. Abutments

KTC abutment condition and distress ratings are provided in Tables 23 (overall ratings) and 31 (for individual abutment types). Two types of abutments were commonly encountered -- full and stub (Figure 36). KTC was asked to determine the performance of spill-thru abutments. Apparently, that design was employed more commonly in Western Kentucky and none were included in the bridges inspected by KTC. In the future, those abutments can be inspected under the Long-Term Monitoring Study. KTC data indicated that the stub and full height abutments were performing similarly except for the Type 104 and Type 302 bridges where the full-height abutments rated lower (in the *fair* to *good* range). Those bridge types included some older bridges with full height masonry abutments that may have contributed to the lower average condition ratings than the bridges with stub abutments.

KYTC has employed integral and semi-integral abutment bridges since 1970. That type of design has been used with cast-in-place concrete tee beams, precast I-beams, pre-cast box beams and steel I-beams and girders (some as retrofits). Some KYTC bridges have concrete beams cast integral with the end diaphragms and the entire assembly is mounted in, but not tied to the abutments (Figure 37). On other bridges the superstructure was cast integral to the abutment, but jointed at piers. While those bridges are not truly integral (some of the superstructures are jointed at piers), they were classified as integral by KTC researchers. That detail has been used in a variety of bridge types. A few small simple-span bridges were observed that utilized beams that were cast into the abutments. As previously noted, KYTC occasionally repairs steel bridges where the abutments are bearing against the beam ends by making those bridges true integral abutment designs. Overall abutment condition rating data shown in Table 31 indicates the KTC-classified integral abutments are performing as well as the non-integral or jointed bridges. KTC previously inspected the performance of the KYTC integral abutment designs and found that most were performing well (11).

KTC inspections frequently revealed erosion around abutments (Figure 38).

9. Stay-in-place forms

Eighteen bridges were inspected that possessed steel stay-in-place forms. The condition ratings are provided in Table 33. On four bridges, the stay-in-place forms were painted. Those had *fair* to *good* condition ratings. Fourteen of the bridges had forms that were galvanized and were performing well with average condition ratings ranging from *very good* to *excellent* (Figure 39). In the past 10 years, KTC personnel conducting coatings research encountered a number of bridges with galvanized stay-in-place forms. In general, most of those are also performing relatively well. In several cases one or more for the forms were observed to have become detached from the decks. In one case, that was related to placement of an overlay where the form was apparently detached by hydro-demolition. In several cases, corrosion of galvanized forms was observed at locations adjacent to leaking deck joints.

One problem with galvanized stay-in-place forms was noted by KYTC Division of Maintenance painting officials. Galvanized steel stay-in-place forms contain mounting tabs that are used to hold the forms in place prior to pouring the deck. Those tabs hinder subsequent maintenance painting of steel beams to which the tabs are attached. Division of Maintenance officials stated that the tabs should be removed after the deck concrete had cured.

10. Deck drains

KTC drain condition and distress ratings are provided in Tables 20 (overall ratings) and 27 (for individual drain types). The KTC ratings indicated that the three types of drains inspected -slot (barrier) drains, scuppers and pipe (tube) drains-were performing satisfactorily for all of the bridge types. The condition ratings for the three drain types were all *very good* to *excellent* for all 7 bridge types. However, several bridges that contained small pipe drains that were clogged (Figure 40). In those cases, there was a large amount of debris in the gutter lines. The KYTC General Maintenance Forms for the District 7 bridges indicated that debris removal from decks/gutter lines and unclogging deck drains were fairly common requirements.

11. Galvanized and non-galvanized steel components

Protective end treatments and guardrails on barrier walls were inspected. Eight non-galvanized end treatments and guardrails were encountered. They rated *poor* to *fair*. Several chain link fences on pedestrian bridges were inspected that were rated *good*. The average condition/distress ratings for the galvanized guardrails are shown in Table 18. The average ratings for those due to corrosion and crash damage were all rated *very good* (Figure 41). The aluminum top rails used with some vertical concrete walls also were performing well.

In 2003, KTC researchers inspected a mainline bridge on I-24 over Ky. 93 in Lyon Co. It is believed to be the only bridge in Kentucky possessing hot-dipped galvanized girders. The bridge was erected in 1977. When first inspected in 1982, the galvanizing possessed white zinc corrosion product in spots (12). In 2003, it was observed throughout the structure. A few spots of ferrous corrosion were also observed at that time. A companion bridge built at the same time and painted with a lead-alkyd system was still in relatively good condition. Both bridges were to be maintenance painted by overcoating in 2004. The resulting duplex coating, paint over galvanizing, should prove extremely durable. KTC researchers are unaware of any other uses of galvanizing on Kentucky bridges. Transportation agencies in other states have routinely used both hot-dipped and spray-applied zinc coatings to protect bearings, joints and transverse stiffeners/diaphragms in shop applications. Those applications are to protect components anticipated to be subject to severe deterioration from leaking deck joints.

Galvanizing has performed well on bridge end treatments and barrier walls in Kentucky. Painting weathered galvanizing can significantly enhance its durability and aesthetic appearance.

12. Deck sealants

KTC researchers sought to identify bridges that had been treated with deck or other concrete sealants. No recent applications could be identified. In the past, KYTC experimented with a variety of deck sealants. The last known use was in the 1970s, when KYTC experimented with the use of boiled linseed oil to seal several bridge decks on I-64 overpass bridges between Frankfort and Lexington. In a recent communication related to concrete sealants, KYTC officials noted that they had not been used in Kentucky citing difficulties in monitoring their application (as most common sealants are clear and are absorbed into concrete like water) and the temporary nature of the protection offered by some sealants.

Closure

Most of the KYTC bridges inspected under this study are in relatively good condition and can benefit from the appropriate actions to rehabilitate/preserve them. Structurally deficient concrete bridges can be strengthened using carbon fiber technology now coming into widespread use. Many bridges inspected by KTC had old barrier wall designs and many lacked proper end treatments. Those deficiencies can be eliminated by rehabilitation actions impacting their functional obsolescence. Preventive maintenance (preservation) can limit/eliminate many types of deterioration of bridge components. If the proper maintenance actions are taken with the 7 bridge types, KTC researchers believe that many of them can serve effectively for an additional 50-100 years.

RECOMMENDATIONS

Related to Bridge Design

1. **Discontinue the use of epoxy sand seals along bridge gutter lines.**
   KYTC officials plan to eliminate this feature when the specification is revised in the near future. Other alternatives should be considered for waterproofing the gutter lines. The Missouri DOT has been studying the use of penetrating sealants to waterproof around slot (barrier) drain gutters/spouts.

2. **Limit the use of deck joints on bridges and employ more new bridges with fully integral abutment designs.**
   Limiting or eliminating deck joints will improve both structure maintainability and durability by eliminating a trouble-prone bridge feature (noting that integral abutment designs don’t work well on some applications such as skewed bridges). Currently, the Division of Bridges Guidance Manual refers to the use of jointless bridges with spans of 400 ft. or less. Other transportation agencies including the Indiana DOT (INDOT) are applying that design to structures up to 1,000-ft. long. The Tennessee DOT (TNDOT) has virtually eliminated deck joints on its bridges with relatively few

maintenance problems (Figure 42) (13).

3. **When deck joints are required, use closed joints to the greatest extent possible (including modular expansion joints).**
   As part of his NCHRP synthesis report on deck joints, Purvis surveyed transportation agencies in the United States and Canada (op. cit. 7). Some agencies have avoided using modular joints due to their past performance, cost, complexity and maintenance requirements. Purvis noted that modular joint manufacturers have upgraded their performance (14). Modular joint test requirements (general performance and fatigue) are provided in several NCHRP reports (15, 16). Those requirements can be used to specify/qualify modular expansion joints.

4. **Use troughs under all deck joints including closed joints.**
   In the past, KYTC has used troughs on bridges with open joints (i.e. finger dams). Both rigid and flexible troughs have been used with varying degrees of success. The Division of Bridges has a rigid trough design that has performed well on the I-75 bridge over the Kentucky River. The primary problem with many troughs is that they become clogged with debris that falls through the open joints. Thereafter, they overflow allowing moisture to degrade bridge elements they were meant to protect. Troughs may be useful when used in conjunction with closed joints such as compression seals or modular joints. They could extend the watertight feature of those joints for years. Closed joints would keep debris out of the troughs allowing them to carry off water unless a joint seal became dislodged. A trough handling only water could readily be mounted directly under the joints of most existing bridges. Trough installation could be incorporated into maintenance projects along with joint replacement. They could be added to bridges at lower cost than joint elimination. In 2002, KTC researchers traveled to Perm, Russia as part of a technical exchange with the Perm Road Committee. They observed the Russian use semi-closed and closed deck joints including sliding plates and poured asphalt joints along with flexible troughs and drain under all deck joints (Figures 43-46). Inspection of the trough assemblies indicated that most were functioning well after years of service.

5. **KTC is currently testing polymer concrete coatings that offer better performance than textured masonry coatings and tints. When that testing is completed and acceptable coatings are identified, they should be considered for routine use on new bridges.**
   Polymer coatings are available that offer a variety of properties including good aesthetics, resistance to damage and vandalism, and much better durability. Those coatings also offer protection to the underlying reinforce concrete from environmental forces. There are growing concerns about the susceptibility of prestressed and post-tensioned concrete beams/girders to corrosion of the reinforcing steel and deterioration of the concrete. Polymer coatings can act as barriers to prevent corrosion and concrete deterioration on those components. They can be applied either in the fabrication shop or in the field. Other transportation agencies are investigating new polymer coatings for use on structures. Caltrans recently used a polyurea coating on all exposed concrete (including beams) on the long San Mateo Bridge in Oakland Bay and the Pennsylvania Turnpike is using polymer coatings on concrete bridge abutments and beams/girders.

6. **Investigate erosion at bridge ends/approaches on bridges built to new KYTC Special Provision 69 to determine its effectiveness.**
   If additional measures are found to be necessary, KYTC could consider Russian design details intended to prevent erosion at bridge ends and embankments. They provide lined drainage systems to carry water runoff to streams and prevent sediment pollution (Figures 47 and 48). The Russians also

use embankment stabilization methods using fine aggregate secured by concrete, wood or fabric grid systems or by using precast concrete panels (See Figure 48).

7. **Improve inspection access to bridges by adding steps/walkways on embankments.**
In the technical exchange visit to Perm, Russia, KTC researchers observed that the Russians provide good access to the undersides of bridges for inspection. Typically, the Russians install precast steps and sidewalks on bridge embankments to facilitate inspector access to abutments and beams (Figure 49). In many cases, access to the undersides of KYTC bridges is hindered by loose aggregate on embankments, fencing, and vegetation.

8. **The KYTC Division of Bridges has employed a number of experimental features on bridges. Those features should be subject to long-term monitoring to assess their current performance.**

Related to Bridge Maintenance

1. **KYTC is currently seeking to eliminate deck joints when conducting bridge rehabilitation projects. If joints cannot be eliminated, replace existing joints with a combination of closed joints and troughs where feasible. Investigate the performance of existing flexible and rigid troughs and consider the development of new trough designs.**
KYTC has also eliminated joints on existing bridges where the abutments have moved and lodged against steel superstructures by making the abutments integral with the superstructures.. During a recent coatings inspection, KTC researchers observed one of those bridges which appeared to be performing well (Figure 50). INDOT has experienced severe bridge deterioration problems due leaking joints and also seeks to remove joints from existing bridges when rehabilitating them (17).

2. **Investigate the use of different joint seals such as polymer foams and asphalt plug joints. Where those joints have been used experimentally, conduct long-term monitoring to assess their performance.**

3. **Perform joint maintenance/repairs more frequently.**
Based on the experience of many transportation agencies, Purvis recommends several actions for improving joint performance and extending their service life (18). Those are:
    - *implement a proactive deck joint maintenance program;*
    - *use deck joint blockouts adjacent to joints when placing a joint system;*
    - *support each replacement joint system with sound concrete;*
    - *install each seal to match ambient temperature;*
    - *ensure that the joint opening size and shape is properly constructed;*
    - *when placing a deck overlay, install the joint system after the overlay is placed;*
    - *protect against unusual joint movement that could damage the joint seal;*
    - *follow the manufacturer's recommendations for selection and installation;*
    - *avoid splices in pre-molded expansion material; and*
    - *protect against snowplow damage.*

4. **As previously noted, KTC is investigating protective coatings for concrete. When acceptable coatings are identified, they should be considered for use on existing bridge concrete to prevent deterioration.**

5. **Limit blacktopping to bridges that need eventual replacement or deck replacement. KYTC is currently expanding the use of asphalt membranes for overlay work especially on low ADT routes. Investigate the use of polymer overlays and polymer asphalts to supplement the use of latex concrete and asphalt membrane overlays.**
Transportation agencies in several states are using thin polymer overlays on a variety of bridges including interstate routes. The Missouri DOT has successfully installed about 200 polymer overlays over the past 15 years. Currently, the Missouri DOT is beginning to experiment with polymer overlays that replace the fine aggregate with sand directly broadcast onto the uncured polymer resin. Relatively short cure times are necessary for the polymer/aggregate overlays and the overlays can usually be put in service on the same day they are placed. Missouri DOT officials estimate that those overlays will have a life of about 15 years. Damage in the overlays can be spot repaired. They state that the polymer overlays cost about one-third of rigid overlays. While not as durable as latex overlays, the polymer overlays would provide lower life-cycle costs as the latex overlays typically last 20-30 years. The one drawback to using polymer overlays is that the deck surface must be in relatively good condition. While in Perm, Russia, KTC researchers observed a bridge possessing a steel deck with a polymer asphalt overlay (Figure 51). The bridge has been in service for about 10 years and the deck appeared to be in good condition. Polymer asphalt requires special equipment to mix the asphalt and polymer at the asphalt plant. The mix is placed like conventional asphalt to a depth of several inches. It provides a wearing surface that resists penetration by deicing salts. It can be placed and the bridge deck can be placed in service shortly thereafter.

6. **Investigate the use of concrete sealers, crack fillers and spall patching materials for concrete maintenance (preservation) on bridges.**
KTC inspections commonly encountered concrete cracking, especially on decks including those with latex overlays (Figure 52). Concrete cracking and excessive permeability both present threats to structure durability. Transportation agencies in other states have used/are using a variety of sealants including silanes, siliconates, siloxanes, methylmethacrylates and others to reduce concrete permeability and its related susceptibility to damage from moisture penetration and the percolation of chlorides to the depth of reinforcement. Research has proven some sealers to be effective in limiting water and chloride intrusion (19). Sealants offer enhanced durability for all concrete components and should be considered by KYTC for bridge maintenance. Several years ago, KTC performed tests using a proprietary sealant and obtained a significant reduction in concrete permeability. One issue of concern is the suitability of using sealants on concrete having significant deicing salt (chloride) penetration. Commercially available treatments exist to remove chlorides from bridge components. However, such treatments may not be necessary. The answer in part is given by the Missouri DOT's use of polymer overlays. The decks those overlays are used on probably have high chloride contents. No effort was made to extract the chlorides prior to application. The polymer overlays used on those decks act as barriers to inhibit significant moisture/deicing salt penetration. Their durability indicates of that any barrier (coating or sealant) will probably be effective in limiting or eliminating reinforced concrete deterioration despite significant levels of chloride contamination.

7. **Employ concrete preservation materials (e.g. coatings, crack fillers, patching compounds and sealers) widely as part of a proactive preventive maintenance program.**

8. **Investigate the use of chloride extraction and cathodic protection to protect concrete bridge elements including decks, barrier walls, piers and abutments.**

9. **Increase steel bridge maintenance painting funding to a sustainable level. Employ spot painting to extend the service lives of existing bridge coatings.**
10. **Consider all options for bridge maintenance planning.**
    *APPENDIX 1 "*A Commentary on KYTC Options for Bridge Management*" provides a review of the conditions of bridges investigated in the study and bridge management options including the use of HBRRP funds for replacement, rehabilitation and preventive maintenance (preservation). Currently, KYTC actions related to preventive maintenance are limited.*

11. **Employ General Maintenance Forms in all KYTC Districts and track implementation of inspector-recommended bridge maintenance actions.**
    Consider developing maintenance guidelines such as the Michigan DOT example in APPENDIX 2 "Michigan DOT Bridge Deck Repair Matrix" to obtain consistent maintenance decision-making throughout all KYTC Districts.

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TABLES

Table 1. Seven Bridge Types Comprising the Majority of KYTC-Owned Bridges.

NBI Bridge Type Code	*Description*	*Number of KYTC Bridges in 1999*	*% of Inventory in 1999*
104	Concrete Tee Beam	1,999	30.86
204	Concrete Continuous Tee Beam	607	9.37
302	Steel Multi-Beam Stringer or Girder	483	7.46
402	Steel Continuous Stringer or Multi-Beam Stringer or Girder	471	7.27
502	Prestressed Concrete Multi-Beam Stringer or Girder	399	6.16
505	Prestressed Concrete, Multiple Box Beam or Girder	928	14.33
602	Prestressed Concrete Continuous Multi-Beam Stringers or Girders	624	9.63

Table 2. Comparison between KYTC (NBI) Condition Ratings and the Rating System Employed by KTC to Evaluate Bridge Elements/Conditions.

Kentucky Transportation Cabinet(KYTC)	*Kentucky Transportation Center (KTC)*
9- Excellent Condition	5- Best Possible Rating, Excellent Condition or Like New
8- Very good Condition	4- Very good condition with Few Flaws
7- Good Condition	3- Average Consisting of Minor Flaws (Fair-Good)
6- Satisfactory Condition	
5- Fair Condition	2- Several Bad Flaws such as Large Spalls and Cracks (Poor-Fair)
4- Poor Condition	1- Poor Condition, Many Defects
3- Serious Condition	0- Lowest Rating, Failed or Non-Existent
2- Critical Condition	
1- “Imminent” Failure Condition	
0- Failed Condition	

Table 3. KTC Bridge Inspection Summary by Type

Total # of bridges in State excluding Culverts	6476
Total # of Bridges in Selected Categories	5511
Total # Bridges Inspected	319
%age Inspected in Selected Categories	5.78
Total Type 104 Bridge Inspected	99
%age 104 Inspected	4.95
Total 204 inspected	71
%age 204Inspected	11.68
Total 302 inspected	37
%age 302 Inspected	7.66
Total 402 inspected	23
%age 402 Inspected	4.88
Total 502 inspected	22
%age 502 Inspected	5.50
Total 505 inspected	33
%age 505 Inspected	3.56
Total 602 inspected	34
%age 602 Inspected	5.45

Table 4. Bridge Inspection Summary by Type, Average Age (1999), Range of Ages (1999) and Average Deck, Superstructure and Substructure Condition Ratings (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections).

Bridge Type	Number of Bridges Inspected	Avg. Age of Bridges (Yrs)	Range of Ages Max./Min. (Yrs)	Avg. Deck Condition Rating	Avg. Superstruct. Condition Rating	Avg. Substruct. Condition Rating
104	99	44.7	82/10	6.41	6.47	6.57
204	71	35.8	62/18	6.94	7.26	6.99
302	37	48.2	98/12	6.55	6.35	6.14
402	23	25.3	37/10	6.85	7.24	7.24
502	22	10.8	29/3	7.50	7.77	7.55
505	33	21.8	38/4	7.00	6.74	7.03
602	34	9.2	29/4	7.56	7.91	7.88

Table 5. Condition Ratings for Deck Elements/Features by Bridge Type (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections)									
Bridge Type/ Rating	**Deck (Composite)**	**Structural Condition**	**Wearing Surface**	**Joints**	**Drains**	**Expansion Devices**	**Curbs, Sidewalks, Medians**	**Railings**	**Lighting or Utilities**
104 Average	6.41	6.41	6.68	5.17	5.81	6.63	6.38	6.68	5.50
104 Max/Min	8/3	8/3	8/4	8/0	8/0	7/4	8/1	8/3	8/3
204 Average	6.94	6.96	6.99	6.31	6.43	6.65	6.97	7.29	7.10
204 Max/Min	8/5	8/5	8/4	8/2	8/0	8/2	8/5	8/5	8/6
302 Average	6.55	6.59	6.88	5.47	5.60	6.71	6.42	6.25	5.70
302 Max/Min	9/4	9/4	8/5	7/4	7/3	7/6	8/3	7/3	7/3
402 Average	6.87	6.91	7.00	6.67	7.43	6.48	7.24	7.36	7.50
402 Max/Min	8/6	8/6	8/6	8/4	8/7	8/2	8/6	8/7	8/7
502 Average	7.50	7.50	7.68	6.71	7.36	7.40	7.50	7.76	7.00
502 Max/Min	8/4	8/4	8/7	8/5	8/5	8/6	8/6	8/7	7/7
505 Average	7.06	7.15	7.06	5.48	7.17	NA	7.13	7.03	5.00
505 Max/Min	8/5	8/5	8/5	8/1	8/5	NA/NA	8/6	8/0	5/5
602 Average	7.56	7.56	7.56	7.63	7.69	7.33	7.50	7.88	7.67
602 Max/Min	8/6	8/6	8/6	8/7	8/7	8/3	8/7	8/7	8/7

Table 6. Deck Types, Ages and Condition Ratings for the 7 Bridge Types (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections)

Bridge/Deck Type	Number of Bridges	Average Age (Yrs) In 1999	Avg. Deck Condition Rating
104 Asphalt Decks	24	48.6	4.72
104 Latex Decks	57	42.7	6.95
104 Non-Overlain Decks	18	45.6	7.00
104 Membrane Decks	1	65.0	7.00
204 Latex Decks	45	35.8	6.76
204 Non-Overlain Decks	25	35.8	7.00
302 Asphalt Decks	8	52.0	5.90
302 Latex Decks	8	35.0	7.00
302 Membrane Decks	1	39.0	5.00
302 No Decks (R.R.)	20	52.4	NA
402 Latex Decks	9	29.4	6.86
402 Non-Overlain Decks	14	21.5	6.86
502 Non-Overlain Decks	21	10.1	7.67
502 Membrane Decks	1	29.0	4.00
505 Asphalt Decks	11	27.5	6.72
505 Non-Overlain Decks	22	19.6	7.24
602 Latex Decks	1	18.0	7.00
602 Non-Overlain Decks	33	8.9	7.57

Table 7. KYTC Inspector Comments on Decks in Inspection Report Forms by %age of Bridge Types

Comment	104 (%)	204 (%)	302 (%)	402 (%)	502 (%)	505 (%)	602 (%)
Deck Deterioration	28.60	17.60	16.22	9.52	--	3.13	3.13
Cracking	28.60	40.54	5.41	47.62	22.73	6.25	31.25
Overlay Det./Crack./Spall.	15.30	18.92	5.41	.00	--	--	3.13
Potholes	5.10	4.05	8.11	14.29	--		3.13
Deteriorating/Leaking Joints	32.65	22.97	24.32	47.62	9.09	15.63	15.63
Spalling Curb/Sidewalk	8.20	8.11	2.70	19.05	--	3.13	--
Railing Damaged-Including Traffic	3.10	1.35	5.41	--	--	9.38	--
Rail Spalling	5.10	--	2.70	--	--		3.13

Table 8. Condition Ratings for Superstructure Elements/Features by Bridge Type (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections)

Bridge Type/ Rating	Superstructure (Composite)	Stringers, Girders, Beams	Floor Beams	Trusses- Main Members	Trusses- Bracing, Portals	Bearing Devices	Alignment/ Structural Members	Deflection/ Vibration under load	Debris on Members
104 Average	6.48	6.48	NA	NA	NA	6.98	7.35	7.38	7.22
104 Max/Min	8/4	8/4	NA	NA	NA	8/3	8/4	8/5	8/5
204 Average	7.26	7.34	N	N	N	6.37	7.66	7.69	7.37
204 Max/Min	8/5	8/5	NA	NA	NA	8/3	8/7	8	8/5
302 Average	6.35	6.35	7.00	NA	5.33	6.27	7.08	6.94	6.42
302 Max/Min	9/4	9/4	7/7	NA	6/5	8/3	9/5	9/5	8/4
402 Average	7.24	7.24	N	NA	NA	6.67	7.57	7.29	7.11
402 Max/Min	8/6	8/6	NA	NA	NA	8/5	8/7	8/5	8/5
502 Average	7.77	7.77	NA	NA	NA	7.86	7.91	7.82	7.89
502 Max/Min	8/4	8/4	NA	NA	NA	8/7	8/7	8/5	8/7
505 Average	6.82	6.82	NA	NA	NA	7.47	7.58	7.58	7.65
505 Max/Min	8/4	8/4	NA	NA	NA	8/6	8/6	8/6	8/6
602 Average	7.91	7.90	NA	NA	8.00	7.91	8.00	8.00	7.97
602 Max/Min	8/7	8/7	NA	NA	8/8	8/7	8/8	8/8	8/7

Table 9. KYTC Inspector Comments on Superstructures in Inspection Report Forms by %age of Bridge Types							
Comment	104 (%)	204 (%)	302 (%)	402 (%)	502 (%)	505 (%)	602 (%)
Girder Deterioration	12.24	0.00	NA	NA	--	--	--
Girder Staining	3.06	0.00	NA	NA	--	--	--
Girder Spalling	4.08	8.11	NA	NA	9.09	15.63	12.50
Traffic Damage to Girder	6.12	6.76	18.92	4.76	--	--	--
Girder Cracking	7.14	1.35	NA	NA	4.55	3.13	6.25
Girder Needs Painting	NA	NA	2.70	--	NA	NA	NA
Girder Rusting	NA	NA	45.95	28.57	NA	NA	NA
Drains Rusting	NA	NA	2.70	--	NA	NA	NA
Bearings Rusting	NA	NA	27.03	47.62	NA	NA	NA
Shoes Rusty	1.02	48.65	--	--	--	--	3.13

Table 10. Condition Ratings for Steel Painting by Bridge Type (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections)							
Bridge Type	**No. Painted**	**Colors**				**Avg. Age of Coating/ (Max/Min)***	**Avg. Coating Rating/ (Max/Min)**
		Blue	Green	Gray	Other		
204	1	1				17(17/17)	7.00
302	31	3	2	21	5	10(20/1)	4.22
402	21	5	-	13	3	18(28/1)	6.90

*Coating ages obtained for 11 bridges.

Table 11. Condition Ratings for Substructure Features/Elements by Bridge Type (KYTC Ratings of Districts 5 & 7 from 1994-96 Inspections)

Bridge Type/ Rating	Substruct. (Composite)	Abutments, Wingwalls	Piers/ or Bents	Alignment/ or Settling	Scour, Erosion	Debris on Seats, Caps	Protection Systems	Abutments, Wingwalls (s.z.d.)	Piers/ or Bents (s.z.d.)	Alignment or Settling Due to Scour
104 Average	6.57	6.75	6.26	7.27	7.00	6.91	NA	7.35	7.24	7.50
104 Max/Min	8/4	8/4	8/4	8/5	8/5	8/5	NA	9/5	9/5	9/5
204 Average	6.99	6.96	7.34	7.34	6.82	6.64	4.00	7.00	7.25	7.80
204 Max/Min	8/4	8/4	8/5	8/5	8/4	8/5	4/4	8/6	8/7	8/7
302 Average	6.14	6.22	6.58	6.94	6.56	6.33	6.33	6.71	7.00	6.57
302 Max/Min	8/3	8/3	8/5	8/3	8/3	8/4	7/6	7/5	7/7	8/5
402 Average	7.24	7.24	7.14	7.52	7.29	6.80	NA	7.50	7.50	8.00
402 Max/Min	8/7	8/7	8/5	8/7	8/6	8/5	NA	8/7	8/7	8/8
502 Average	7.55	7.57	7.60	7.86	7.82	7.85	NA	7.83	8.00	7.86
502 Max/Min	8/5	8/5	8/7	8/5	8/5	8/7	NA	8/7	8/8	8/7
505 Average	7.06	7.00	7.38	7.52	7.34	7.54	8.00	7.50	7.33	7.61
505 Max/Min	8/4	8/4	8/6	8/5	8/6	8/6	8/8	8/6	8/6	8/6
602 Average	7.88	7.88	7.91	8.00	7.94	7.79	7.83	7.55	7.58	7.69
602 Max/Min	8/7	8/7	8/7	8/8	8/7	8/6	8/7	8/7	8/7	8/7

Table 12. KYTC Inspector Comments on Substructures Inspection Report Forms by %age of Bridge Types

Comment	104 (%)	204 (%)	302 (%)	402 (%)	502 (%)	505 (%)	602 (%)
Pier/Abut/Wingwall Deterioration	31.63	10.81	--	--	--	--	--
Pier/Abut/Wingwall Cracking	17.35	18.92	5.41	23.81	22.73	--	15.63
Pier/Abut/Wingwall Spalling	19.39	17.57	24.32	14.29	9.09	3.13	12.50
Pier/Abut/Wingwall Staining	9.18	2.70	8.11	--	4.55	3.13	--
Settling/Abut. Move. Etc.	--	8.11	--	--	--	--	--
Girders Jammed into Abut.	--	4.05	--	--	--	--	--

Table 13. KYTC Inspector Comments on Maintenance/Other Issues in Inspection Report Forms by %age of Bridge Types

Comment	104 (%)	204 (%)	302 (%)	402 (%)	502 (%)	505 (%)	602 (%)
Dirty Deck	6.12	12.16	10.81	14.29	4.55	12.50	9.38
Clogged Drains	8.16	1.35	2.70	4.76	4.55	3.13	0.00
Rough Approach/Impact	5.10	9.46	--	--	9.09	6.25	9.38
Brush Around Bridge	5.10	13.51	--	--	4.55	3.13	
Erosion Abut./Other	6.12	2.70	10.81	14.29	4.55	--	3.13
Exposed Rebar	20.41	18.92	5.41	9.52	4.55	18.75	--
Masonry Coating Fail.	--	--	2.70	--	4.55	--	--
Limestone Blocks Deteriorating	--	--	2.70	--	--	--	--
Pigeon Dropping Build-up	--	--	5.41	--	--	--	--
Graffiti	--	--	--	--	--	--	3.13

Table 14. Average Overall Bridge Condition Ratings for the Decks, Superstructures and Substructures from KYTC Inspection Reports (1994-96) and (2001-03)

Bridge Type	Avg. Deck Condition Rating (1994-96)	Avg. Deck Condition Rating (2001-03)	Avg. Superstructure Condition Rating(1994-96)	Avg. Superstructure Condition Rating(2001-03)	Avg. Substructure Condition Rating (1994-96)	Avg. Substructure Condition Rating (2001-03)
104	6.41	5.70	6.47	5.97	6.57	5.82
204	6.94	6.17	7.26	6.64	6.99	6.43
302	6.55	6.00	6.35	6.04	6.14	5.58
402	6.85	6.18	7.24	6.65	7.24	6.71
502	7.50	6.32	7.77	6.32	7.55	6.14
505	7.00	6.13	6.74	6.07	7.03	6.03
602	7.56	6.48	7.91	6.76	7.88	6.67

Table 15. Average Bridge Condition Ratings for Deck Wearing Surfaces, Joints, and Expansion Devices from KYTC Inspection Reports (1994-96) and (2001-03)

Bridge Type	Avg. Wearing Surface Condition Rating(1994-96)	Avg. Wearing Surface Condition Rating(2001-03)	Avg. Joint Condition Rating (1994-96)	Avg. Joint Condition Rating (2001-03)	Avg. Exp Device Condition Rating (1994-96)	Avg. Exp. Device Condition Rating (2001-03)
104	6.68	5.88	5.17	5.24	6.63	6.38
204	6.99	6.08	6.31	6.18	6.65	6.26
302	6.88	5.81	5.47	5.47	6.71	6.00
402	7.00	5.86	6.67	5.67	6.48	5.67
502	7.68	6.50	6.71	5.67	7.40	6.40
505	7.06	6.03	5.48	5.25	NA	NA
602	7.56	6.44	7.63	6.35	7.33	6.36

Table 16. Bridge Maintenance Needs from District 7 for 2002-2004 General Maintenance Forms for Bridges Inspected by KTC in 1998 that Remain in Service. Specific Maintenance Need v. %age for Each Bridge Type

Bridge Maintenance Needs	104 (%)	204 (%)	302 (%)	402 (%)	502 (%)	505 (%)	602 (%)
Clean decks	38	26	4	36	10	21	13
Clean drains	21	5	--	--	5	3	--
Seal/repair joints	30	16	7	21	5	14	3
Patch potholes in deck	11	9	4	7	--	7	--
Repair spalling curb/barrier walls	--	4	--	--	--	--	--
Mill & wedge bridge ends	27	4	--	36	10	10	6
New overlay or membrane	11	16	7	29	--	10	--
Re-deck bridge	--	2	--	--	--	--	--
Repair potholes in approach	11	--	4	--	--	3	3
Repair approaches/correct roadway drainage	--	4	--	7	--	--	--
Repair pier caps/columns	7	--	--	--	--	--	--
Repair embankment erosion around abutments and aprons	4	--	--	--	--	--	--
Clean abutment seats/pier caps/members	--	11	--	7	--	--	--
Repair/paint/replace expansion devices	--	26	4	7	--	--	--
Paint all structural steel	--	--	14	7	--	--	--
Repair spalling/scaling concrete	4	--	25	--	5	3	--
Repair traffic damage to beams	1	--	--	--	--	--	--
Cut brush	27	19	11	21	10	3	--
Channel work	10	2	--	--	--	3	3
Utility repair/painting	--	2	--	--	--	--	--
No work required	34	28	12	8	15	12	--
Replace bridge	10	0	7	0	0	0	--

Table 17. Average KTC Bridge Condition Ratings for Deck Overall Condition, Distress, Surface Finish and Epoxy Sand Seals from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Deck Overall Condition	Ride Quality Overall	Spalls/ Patches	Cracks	Finish	Tyned	Broomed	Epoxy Sand Seal
104 Average	3.42	4.12	3.69	3.69		2.93	1.43	0.85
104 Max/Min	5/1	5/1	5/1	5/2		4/1	5/0	5/0
204 Average	3.82	4.83	3.83	3.77		4.16	1.72	1.38
204 Max/Min	5/2	5/3	5/2	5/2		5/2	4/0	5/0
302 Average	3.63	3.67	4.00*	3.50		5.00*	1.40*	2.20*
302 Max/Min	5/1	5/3	5/1	5/1		5/-	4/0	5/0
402 Average	3.80	3.91	4.00*	3.61		4.10	0.67*	0.64
402 Max/Min	5/2	5/3	5/2	5/2		5/3	1/0	4/0
502 Average	4.26	4.95	4.41	4.09		3.82	3.33*	0.38
502 Max/Min	5/3	5/4	5/3	5/3		5/2	5/1	5/0
505 Average	3.91	4.42	3.97	3.73		3.57*	1.00	0.18
505 Max/Min	5/2	5/2	5/2	5/2		5/1	4/0	1/0
602 Average	4.12	4.34	4.21	3.76		3.92	2.22*	0.24
602 Max/Min	5/2	5/1	5/1	5/3		5/3	4/0	2/0

* Less than ten data ratings provided by KTC researchers.

Table 18. Average KTC Bridge Condition Ratings for End Treatment Distress, Barrier Wall Condition Ratings/Distress and Guardrail Condition (Galvanized and Aluminum) from 1998 Inspections (Ratings on the KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	End Treatment Corrosion	End Treatment Crash Damage	Barrier Wall Condition	Barrier Wall Spalls	Barrier Wall Impacts	Barrier Wall Cracks	Galvanized Guardrail Condition	Aluminum Guardrail Condition
104 Average	4.36	4.34	3.75	3.61	4.07	3.72	4.40*	4.67
104 Max/Min	5/1	5/2	5/1	5/2	5/1	5/0	5/3	5/4
204 Average	4.20	4.18	4.05	4.03	4.29*	3.84	--	4.73
204 Max/Min	5/1	5/3	5/2	5/2	5/2	5/2	--	5/2
302 Average	5.00*	4.33*	3.67*	3.50*	4.00*	3.75*	4.67*	3.80*
302 Max/Min	5/5	5/3	5/3	5/2	5/3	4/3	5/4	5/2
402 Average	4.33*	4.57*	3.96	3.83*	4.00*	3.94	--	5.00
402 Max/Min	5/4	5/4	5/3	4/3	4/4	5/4	--	5/5
502 Average	5.00	4.67	4.16	4.20	5.00*	4.06	4.67	5.00
502 Max/Min	5/5	5/3	5/3	5/3	5/5	5/3	5/4	5/5
505 Average	4.75	4.71*	3.71	3.45	4.33*	3.79	4.67	--
505 Max/Min	5/3	5/4	5/1	5/1	5/4	4.21	5/3	
602 Average	4.88	4.53	4.04	3.94	4.13*	3.86	--	5.00*
602 Max/Min	5/4	5/3	5/3	5/1	5/2	5/2	--	5/5

* Less than 10 ratings by KTC researchers.

Table 19. Average KTC Bridge Condition Ratings for Approach Slab Distress and Approach Condition/Distress from 1998 Inspections (Ratings on the KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Approach Slab Settlement	Approach Slab Cracking	Approach Slab Heaving	Approach Wedging/Patching Condition	Approach Pavement Sag	Approach Slope Failure	Approach Erosion
104 Average	--	--	--	3.48	3.62	4.75*	3.53
104 Max/Min	--	--	--	5/2	5/2	5/4	5/1
204 Average	NR**	3.00***	NR	4.08	4.14*	NR	3.58
204 Max/Min	--	3/-	--	5/3	5/3	--	5/0
302 Average	--	--	--	4.00*	NR	NR	3.27
302 Max/Min	--	--	--	4/4	--	--	5/1
402 Average	4.00*	4.00*	3.00*	3.50*	NR	NR	3.91
402 Max/Min	5/3	5/3	3/-	4/3	--	--	5/2
502 Average	4.33*	4.33*	5.00*	3.29*	3.25*	3.50*	3.91*
502 Max/Min	5/4	5/4	5/-	4/2	5/2	5/2	5/2
505 Average	NR	NR	NR	3.75*	4.00*	NR	3.27
505 Max/Min	--	--	--	4/3	4/-	--	5/1
602 Average	4.12*	4.34*	4.21*	3.50	3.71*	4.00*	3.85
602 Max/Min	5/2	5/1	5/1	4/2	4/3	4/-	5/1

* Less than 10 ratings by KTC researchers

** Not Rated

*** Only one bridge with approach slabs for this bridge type

Table 20. Average KTC Bridge Condition Ratings for Drain Condition/Distress and Deck Joint Condition/Performance/Distress from 1998 Inspections (Ratings on the KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Drain Overall Condition	Drain Clogging	Debris in Gutter	Joint Overall Condition	Joint Ride Quality	Joint Watertight.	Joint Material Spalling	Joint Seal Tearing/ Detaching	Debris Build-up at Joint	Loose/ Broken Joint
104 Average	4.60	3.36	2.83	3.08	4.12	2.64	3.46	3.24	3.46	4.00
104 Max/Min	5/0	5/0	5/0	5/1	5/1	5/0	5/2	5/1	5/1	5/2
204 Average	4.78*	4.00*	3.67*	4.00	3.97	2.85	3.26	2.71	3.02	3.00*
204 Max/Min	5/3	5/2	5/3	5/1	5/2	5/1	4/1	4/1	5/1	3/3
302 Average	4.50*	4.00*	4.00*	3.00*	4.00*	2.71*	3.75*	3.00*	2.80*	NR
302 Max/Min	5/4	5/3	5/3	5/0	5/3	5/0	5/3	3/-	4/1	--
402 Average	5.00*	4.60*	4.00*	3.45	3.73	3.36	3.44*	2.63*	3.00	2.33*
402 Max/Min	5/5	5/3	5/2	5/2	5/3	5/0	5/1	51	4/2	3/1
502 Average	4.33	5.00	4.25	3.17*	4.38*	3.83*	4.00*	4.00*	3.20*	2.00*
502 Max/Min	5/4	5/5	5/1	5/1	5/2	5/2	4/4	4/4	4/2	2/-
505 Average	4.93	4.54	3.77	3.18	4.33	3.75*	3.20*	3.00*	3.20*	NR
505 Max/Min	5/4	5/2	5/1	5/2	5/3	5/1	4/3	4/2	4/1	-/-
602 Average	4.92	4.62	3.92	3.33	4.12	3.59	3.18	2.87	3.41	2.20*
602 Max/Min	5/4	5/2	5/1	5/1	5/2	5/1	5/1	5/1	4/1	5/1

* Less than 10 ratings by KTC researchers

Table 21. Average KTC Bridge Condition Ratings for Bearing Overall Condition and Distress from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Bearing Condition Overall	Excessive Tilt	Slid off Plate	Deformed	Corrosion
104 Average	3.9*	2.50*	NR	5.00*	3.75*
104 Max/Min	4/1	4/1	--	1	5/2
204 Average	3.94	3.41	3.50*	3.60*	3.00
204 Max/Min	5/1	5/0	5/2	5/2	5/2
302 Average	4.46	5.00*	5.00*	4.67*	3.56*
302 Max/Min	5/3	5/5	5/5	5/4	5/1
402 Average	4.36	4.50*	4.50*	5.00*	3.71
402 Max/Min	5/3	5/3	5/4	5/5	5/2
502 Average	NR	NR	NR	5.00*	5.00*
502 Max/Min	--	--	--	5/-	--
505 Average	5.00*	NR	NR	NR	5.00*
505 Max/Min	5/-	--	--	--	5/1
602 Average	4.69*	3.00*	4.50*	NR	2.75*
602 Max/Min	5/2	3/-	5/4	--	4/2

* Less than 10 ratings by KTC researchers

Table 22. Average KTC Bridge Condition Ratings for Concrete and Steel Girder/Beam Overall Condition and Distress from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Beam/Girder Overall Condition	Vehicle Impact	Vandalism (Non-Graffiti)	Corrosion (Steel)	Staining (Concrete)	Damaged Concrete
104 Average	3.43	5.00*	4.67*	--	3.70	4.04
104 Max/Min	5/2	5/5	5/4	--	5/2	5/1
204 Average	3.96	NR	NR	--	3.93	4.68
204 Max/Min	5/2	--	--	--	5/3	5/3
302 Average	3.57	4.00*	5.00*	3.50	--	--
302 Max/Min	5/1	4/-	5/-	5/1	--	--
402 Average	3.95	NR	NR	4.48	--	--
402 Max/Min	5/3	--	--	5/3	--	--
502 Average	4.71	NR	NR	--	4.67*	4.82
502 Max/Min	5/4	--	--	--	5/4	5/4
505 Average	4.09	NR	NR	--	3.20*	4.22
505 Max/Min	5/2	--	--	--	4/2	5/2
602 Average	4.50	NR	NR	--	4.33*	4.90
602 Max/Min	5/2	--	--	--	5/4	5/4

* Less than 10 ratings by KTC researchers

Table 23. Average KTC Bridge Condition Ratings for Embankment Distress and Abutment Condition/Distress from 1998 Inspections (Ratings on the KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Embankment Erosion	Abutment Settlement	Bump in Road Due to Abutment Settlement	Abutment Overall Condition	Abutment Cracking	Abutment Spalling	Abutment Tilting	Abutment Staining
104 Average	3.50	4.50*	4.50*	3.74	3.58	4.50	4.50*	3.32
104 Max/Min	5/1	5/4	5/4	5/2	5/1	5/1	5/4	5/1
204 Average	3.56	NR	4.67*	3.88	3.63	3.83	3.43*	3.15
204 Max/Min	5/1	--	5/4	5/2	5/2	5/1	5/0	5/0
302 Average	3.38	NR	NR	3.60	3.11	3.18	5.00*	3.00
302 Max/Min	5/2	--	--	5/2	5/0	5/2	5/-	5/0
402 Average	4.63*	5.00*	NR	4.14	3.93	4.67*	5.00*	3.81
402 Max/Min	5/4	5/-	--	5/3	5/3	5/4	5/-	5/2
502 Average	4.18	NR	NR	3.88	3.64	4.60*	5.00*	3.81
502 Max/Min	5/3	--	--	5/3	5/2	5/3	5/-	5/3
505 Average	2.80*	NR	4.00*	3.58	3.56	4.50*	5.00*	3.06
505 Max/Min	4/2	--	4/-	5/2	4/2	5/4	5/-	5/1
602 Average	4.59	NR	NR	4.02	3.59	3.92*	4.25*	3.09
602 Max/Min	5/2	--	--	5/1	5/2	5/2	5/2	5/1

* Less than 10 ratings by KTC researchers

Table 24. Average KTC Bridge Condition Ratings for Pier Overall Condition and Distress from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Pier Overall Condition	Pier Spalling	Pier Splitting-Cracking	Pier Rusting-Rust Spots	Pier Staining Leakage	Vehicle Collision Damage
104 Average	3.13	2.95	3.03	3.10	2.80	3.67*
104 Max/Min	5/1	5/1	5/1	5/1	5/1	5/1
204 Average	4.48	4.41	4.31	4.16	4.07	3.79
204 Max/Min	5/2	5/3	5/2	5/2	5/3	5/3
302 Average	3.30	2.73	3.00	3.82	3.10	3.50*
302 Max/Min	5/1	5/1	5/1	5/2	4/2	4/3
402 Average	4.49	4.09*	4.33*	4.40*	3.84	4.25*
402 Max/Min	5/2	5/2	5/3	5/3	5/2	5/-
502 Average	4.25*	4.33*	4.67*	4.50*	3.67*	NR
502 Max/Min	5/3	5/3	5/4	5/4	4/3	--
505 Average	4.06*	4.00*	3.86*	3.67*	2.50*	3.00*
505 Max/Min	5/2	5/3	5/2	5/3	4/1	3/-
602 Average	4.96	4.67	5.00*	5.00*	4.20	4.67*
602 Max/Min	5/4	5/3	5/5	5/5	5/1	5/4

* Less than 10 ratings by KTC researchers

Table 25. Average KTC Bridge Condition Ratings for Overall Aesthetics and Distress from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Overall Aesthetic Condition	Graffiti	Staining	Vehicle Collision Damage	Debris	Vegetation	Cracking	Repair	Spalling/ Patching
104 Average	3.24	3.43	2.93	3.75*	3.17	3.41	2.96	3.67*	3.07
104 Max/Min	5/1	5/1	4/1	5/2	5/1	5/2	5/2	5/3	5/1
204 Average	3.77	3.38	3.31	3.50*	2.85	3.33*	3.75*	3.00*	4.00*
204 Max/Min	5/2	4/1	4/1	4/3	4/2	4/2	4/3	3/3	4/-
302 Average	3.09	3.29*	2.50	3.00*	2.67*	3.29*	3.00*	2.00*	2.50*
302 Max/Min	4/2	4/1	4/1	3/-	3/2	4/2	4/2	3/-	3/2
402 Average	3.67	3.33*	3.67*	NR	3.00*	3.50*	3.5*0	NR	NR
402 Max/Min	4/3	4/3	4/3	--	3/3	4/3	4/3	--	--
502 Average	4.18	3.63*	4.00*	NR	3.40*	3.57*	NR	NR	NR
502 Max/Min	5/3	5/2	5/3	--	4/3	4/2	--	--	--
505 Average	3.47	3.00*	3.08	NR	3.30*	3.11*	3.25*	2.00*	NR
505 Max/Min	4/2	4/2	5/1	--	5/2	4/1	4/2	3/1	--
602 Average	3.99	3.17	3.17*	NR	3.50	3.75*	2.75*	NR	2.00*
602 Max/Min	5/2	4/1	4/2	--	4/2	4/3	4/2	--	2/-

* Less than 10 ratings by KTC researchers

Table 26. Number of Barrier Walls Inspected by KTC Researchers for Each Bridge Type Along with Average Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Concrete Pigeon Pipe	Concrete Post & Rail	New Jersey	Concrete Wall & Guardrail	Vertical Concrete Wall Misc.	Concrete Wall Rehab. Type	Concrete Curb & Guardrail	Concrete Wall & Aluminum Rail	Galvanized Post & Guardrail	Other
104 Average	3.27	3.74	4.28*	NR	3.50*	4.00*	--	3.95	NR	NR
104 Number Insp.	11	29	11	2	4	2	--	36	3	1
204 Average	--	3.50*	3.88*	--	4.00*	4.00*	--	4.03	--	NR
204 Number Insp.	--	2	10	--	1	2	--	55	--	1
302 Average	--	3.00*	--	--	--	--	NR	4.00*	3.00*	NR
302 Number Insp.**	--	1	--	--	--	--	1	7	4	3
402 Average	--	--	4.14*	--	--	--	--	3.75*	--	--
402 Number Insp.	--	--	10	--	--	--	--	12	--	--
502 Average	--	--	4.13	4.00*	--	--	4.50*	--	--	4.00*
502 Number Insp.	--	--	26	2	--	--	2	--	--	2
505 Average	--	--	4.00*	3.00*	--	--	4.00	--	NR	5.00*
505 Number Insp.	--	--	5	2	--	--	20	--	2	2
602 Average	--	--	4.08	--	3.50*	--	--	--	--	--
602 Number Insp.	--	--	31	--	2	--	--	--	--	--

* Less than 10 ratings by KTC researchers

** Roadway bridges

Table 27. Number and Type of Drains Inspected by KTC Researchers for Each Bridge Type Along with Average Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Slot Drains	Scuppers	Pipe Drains
104 Average	5.00*	4.45*	4.64
104 Number Insp.	4	10	42
204 Average	--	4.00*	5.00*
204 Number Insp.	--	2	6
302 Average	--	--	4.67*
302 Number Insp.**	--	--	3
402 Average	--	--	5.00*
402 Number Insp.	2	1	9
502 Average	5.00*	5.00*	--
502 Number Insp.	7	1	--
505 Average	5.00*	5.00*	5.00*
505 Number Insp.	2	2	13
602 Average	5.00*	5.00*	4.75*
602 Number Insp.	1	7	7

* Less than 10 ratings by KTC researchers
** Roadway bridges

Table 28. Number and Type of Deck Joints Inspected by KTC Researchers for Each Bridge Type Along with Average Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Compression Seal	Strip Seal	Silicon Seal	Sliding Plate	Segmental	Modular	Poured Asphalt
104 Average	3.36	4.00	3.30	3.00*	3.25*	--	2.82
104 Number Insp.	40	10	12	1	8	--	27
204 Average	3.49	4.00*	3.00*	3.45	--	--	3.40*
204 Number Insp.	40	2	1	34	--	--	5
302 Average	3.50*	--	4.00*	4.33*	5.00*	--	4.00*
302 Number Insp.**	6	--	1	4	1	--	1
402 Average	3.25	--	--	3.17*	--	3.00*	3.78*
402 Number Insp.	18	--	--	6	--	1	10
502 Average	3.67*	--	4.00*	--	--	3.00*	--
502 Number Insp.	6	--	2	--	--	1	--
505 Average	--	--	--	--	--	--	3.18
505 Number Insp.	--	--	--	--	--	--	11
602 Average	3.63	--	--	--	--	--	--
602 Number Insp.	24	--	--	--	--	--	--

* Less than 10 ratings by KTC researchers
** Roadway bridges

Table 29. Number and Type of Expansion Devices Inspected by KTC Researchers for Each Bridge Type Along with Average Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Rockers	Sliding Plates	Bearing Pads
104 Average	4.48*	NR	5.00*
104 Number Insp.	65	2	6
204 Average	--	4.00*	5.00*
204 Number Insp.	--	2	6
302 Average	5.00*	4.50	4.67*
302 Number Insp.**	4	7	--
402 Average	4.00*	4.75*	5.00*
402 Number Insp.	12	7	3
502 Average	--	--	NR
502 Number Insp.	--	--	5
505 Average	--	--	5.00*
505 Number Insp.	--	--	1
602 Average	NR	5.00*	5.00*
602 Number Insp.	2	7	9

* Less than 10 ratings by KTC researchers
** Roadway bridges

Table 30. Number and Type of Embankments Inspected by KTC Researchers for Each Bridge Type Along with Average Erosion Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	None	Aggregate	Soil	PCC	Rockwall	Aggregate & Soil Slopes	PCC & Soil	Rockwall & Soil	PCC & Reinforced Earth	Other
104 Average	4.33*	4.17	3.20	NR	--	2.60*	2.00*	2.00*	--	--
104 Number Insp.	25	23	23	3	--	5	1	1	--	--
204 Average	3.50*	4.54	3.44	3.06	--	NR	3.50*	3.00*	--	--
204 Number Insp.	2	24	11	29	--	1	2	2	--	--
302 Average		4.50*	3.00*	3.00*	NR	--	--	--	--	--
302 Number Insp.**	--	6	1	6	2	--	--	--	--	--
402 Average	NR	4.66*	4.00*	NR	--	--	--	3.75*	NR	--
402 Number Insp.	1	14	3	3	--	5.00*	--	12	1	--
502 Average	4.00*	4.40*	5.00*	4.00*	--	3.00*	--	--	--	NR
502 Number Insp.	13	5	2	2	--	1	--	--	--	1
505 Average	2.5*	3.00*	--	--	--	3.00*	--	--	--	--
505 Number Insp.	30	2	--	--	--	1	--	--	--	--
602 Average	NR	4.60	4.00*	4.71*	5.00*	4.50*	--	--	--	--
602 Number Insp.	2	15	3	9	2	3	--	--	--	--

* Less than 10 ratings by KTC researchers

** Roadway bridge

Table 31. Average KTC Bridge Condition Ratings for Stub and Full Abutments & Integral and Non-Integral Designs from 1998 Inspections (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Full Abutments	Stub Abutments	Integral Abutments	Non-Integral Abutments
104 Average	3.33	4.25	3.52	3.83*
104 Number Insp.	49	50	94	4
204 Average	3.00*	3.88	4.00*	3.33
204 Number Insp.	4	64	4	61
302 Average	2.90*	3.42	3.50*	3.57
302 Number Insp.	21	14	3	34
402 Average	4.00*	4.30	--	4.36
402 Number Insp.	1	22	--	23
502 Average	3.94	4.00	4.13	3.67*
502 Number Insp.	16	5	19	3
505 Average	3.53	4.00*	3.58	--
505 Number Insp.	29	3	32	--
602 Average	5.00*	4.15	4.63	4.00*
602 Number Insp.	5	28	15	18

* Less than 10 ratings by KTC researchers

Table 32. Number and Type of Piers Inspected by KTC Researchers for Each Bridge Type Along with Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Solid	Column w/ Web	Column (Open)	Cantilever
104 Average	3.56	2.66	3.16*	--
104 Number Insp.	23	24	5	--
204 Average	4.13*	4.90*	4.35	4.50*
204 Number Insp.	4	3	56	3
302 Average	3.30*	2.35*	2.75*	--
302 Number Insp.	5	4	3	--
402 Average	5.00*	--	4.47	--
402 Number Insp.	3	--	19	--
502 Average	5.00*	3.50*	--	5.00*
502 Number Insp.	1	1	--	1
505 Average	NR	3.00*	--	--
505 Number Insp.	5	1	--	--
602 Average	5.00*	5.00*	5.00	5.00*
602 Number Insp.	9	6	14	1

* Less than 10 ratings by KTC researchers

Table 33. Number and Type of Stay-in-Place Forms Inspected by KTC Researchers for Each Bridge Type Along with Condition Ratings Where Provided (Ratings on KTC 0-5 Six-Point Condition Ratings Scale).

Bridge Type/ Rating	Painted Stay-In-Place Forms	Galvanized Stay-In-Place Forms
104 Average	--	NR
104 Number Insp.	--	1
204 Average	--	5.00
204 Number Insp.	--	3
302 Average	3.00	--
302 Number Insp.	4	--
402 Average	--	4.50
402 Number Insp.	--	2
502 Average	--	4.00
502 Number Insp.	--	1
505 Average	--	5.00
505 Number Insp.	--	2
602 Average	--	4.80
602 Number Insp.	--	5

FIGURES

Figure 1. Type 104 Concrete Tee Beam Bridge.

Figure 2. Type 505 Prestressed Concrete, Multiple Box Beam or Girder Bridge.

Figure 3. Type 602 Prestressed Concrete Continuous Multi-beam Stringers or Girder Bridge.

Figure 4. Type 204 Continuous Concrete Tee Beam Bridge.

Figure 5. Type 302 Steel Multi-beam Stringer or Girder Bridge.

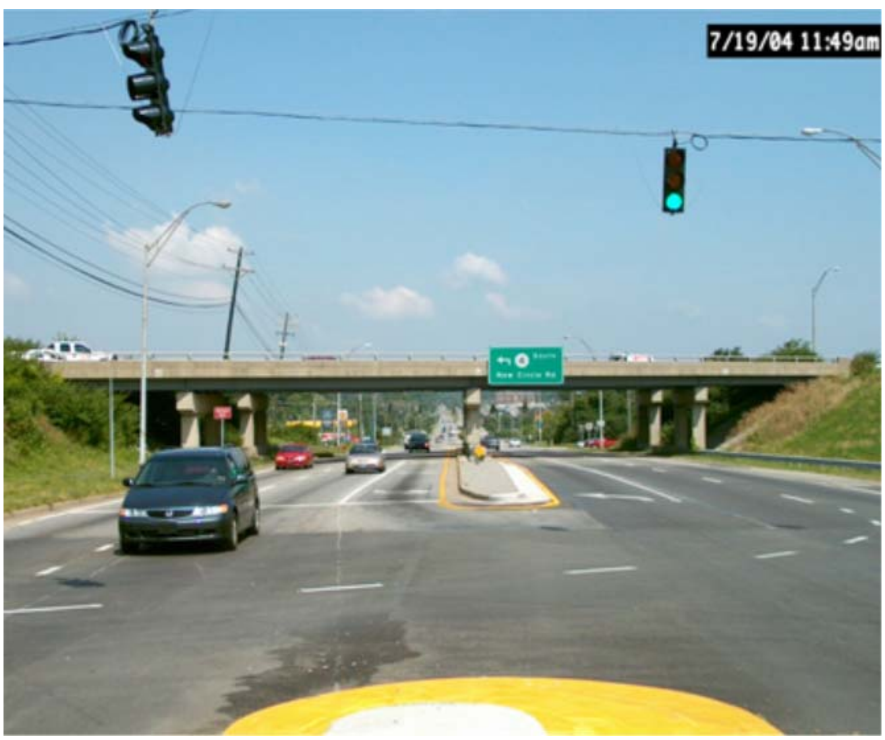

Figure 6. Type 402 Steel Continuous Stringer or Multi-beam Stringer or Girder Bridge.

Figure 7. Type 502 Prestressed Concrete Multi-beam Stringer or Girder Bridge.

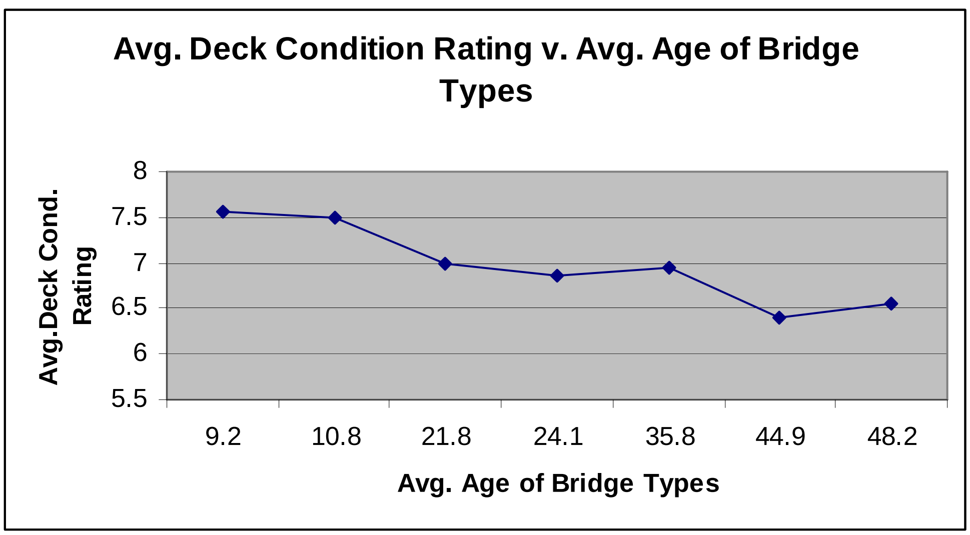

Figure 8. Avg. Overall Deck Condition Ratings for All Bridge Types v. Avg. Age of the Respective Bridge Types.

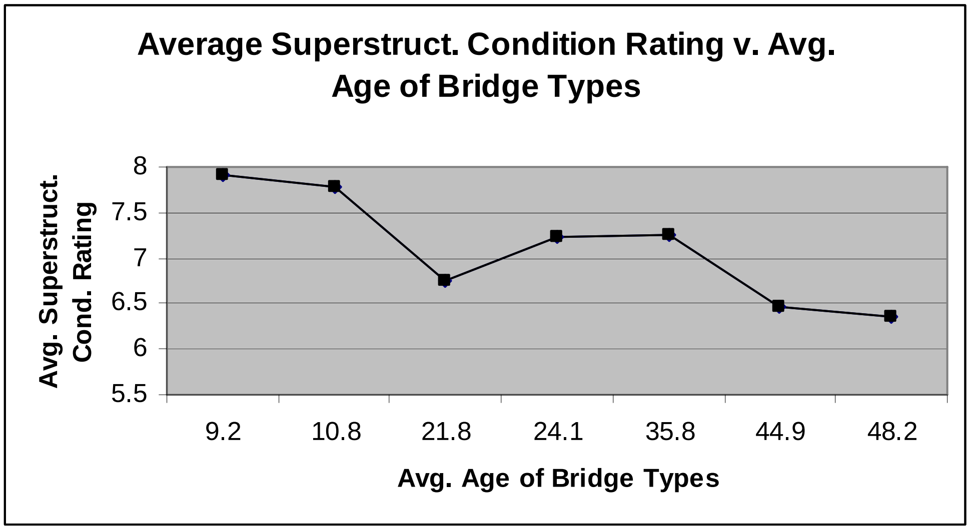

Figure 9. Avg. Overall Superstructure Condition Ratings for All Bridge Types v. Avg. Age of the Respective Bridge Types.

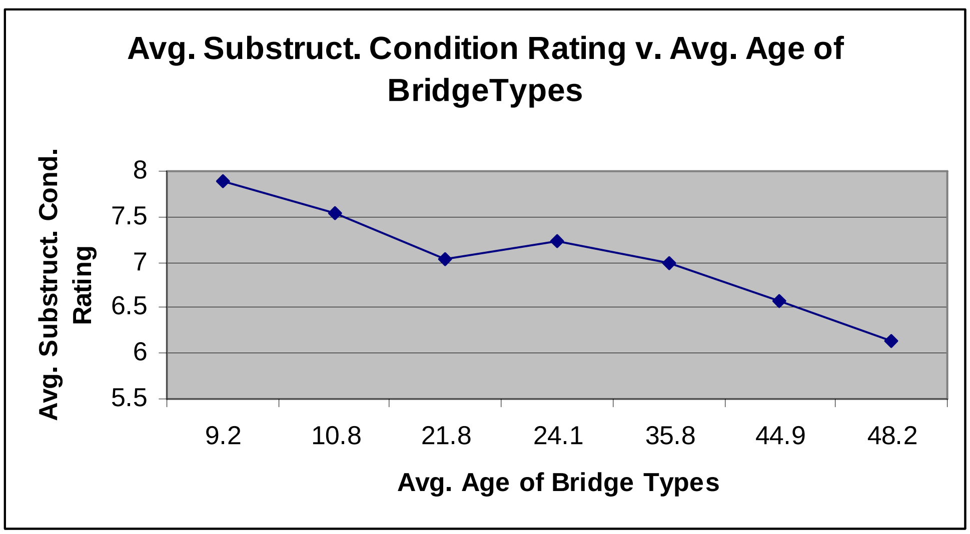

Figure 10. Avg. Overall Substructure Condition Rating v. Avg. Age of the Respective Bridge Types.

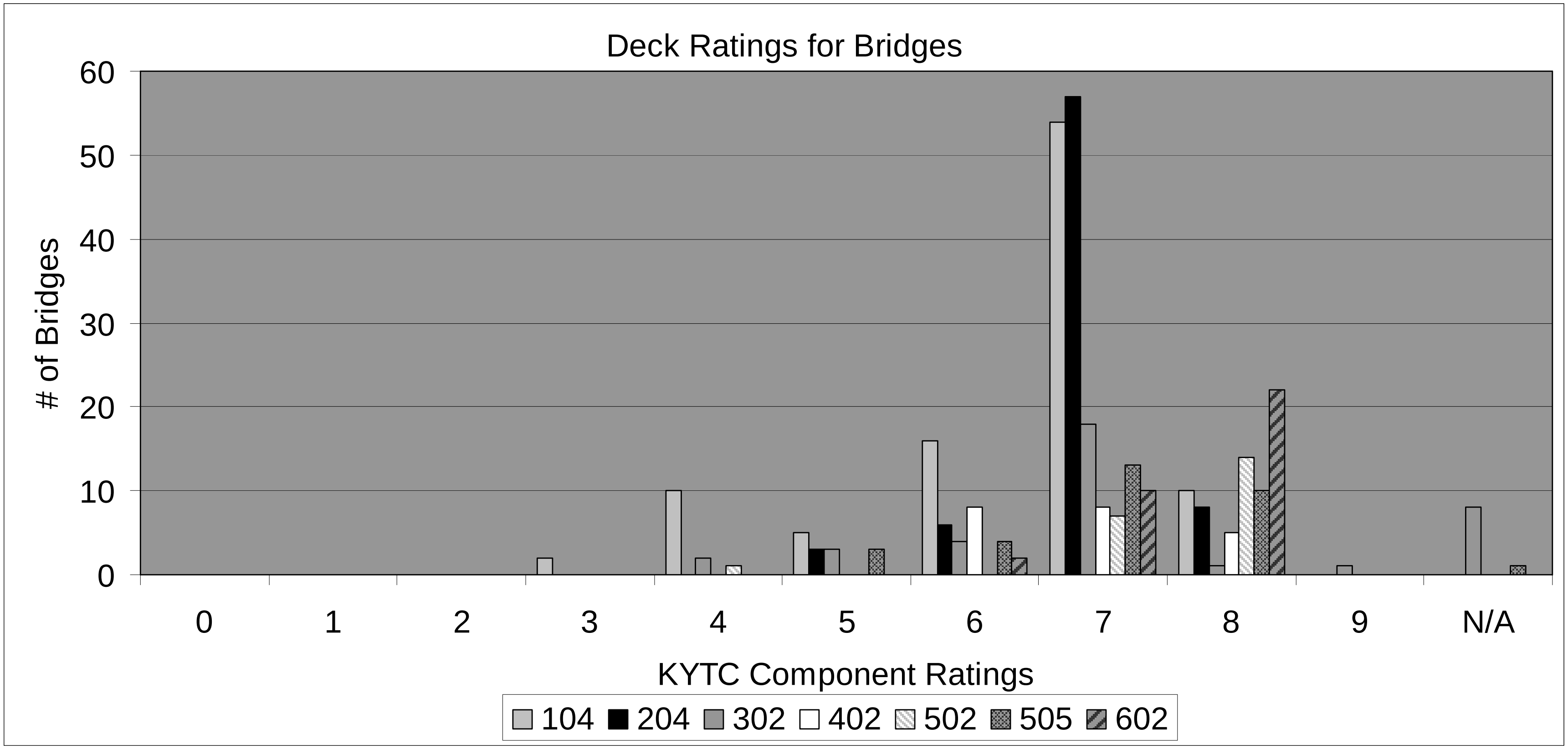

Figure 11. Avg. Overall Deck Condition Ratings v. Number of Bridges by Category of Bridge Types Inspected.

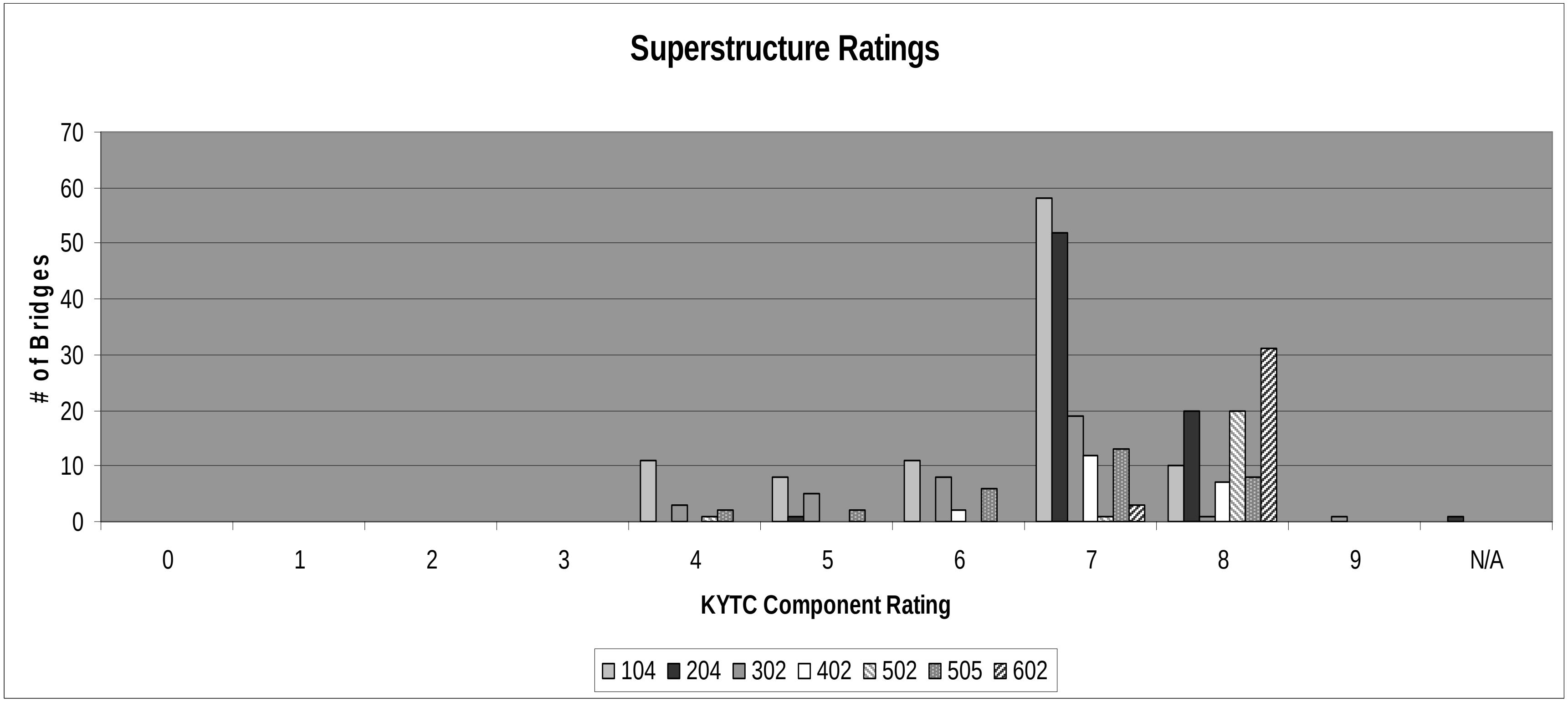

Figure 12. Avg. Overall Superstructure Condition Ratings v. Number of Bridges by Category of Bridge Types Inspected.

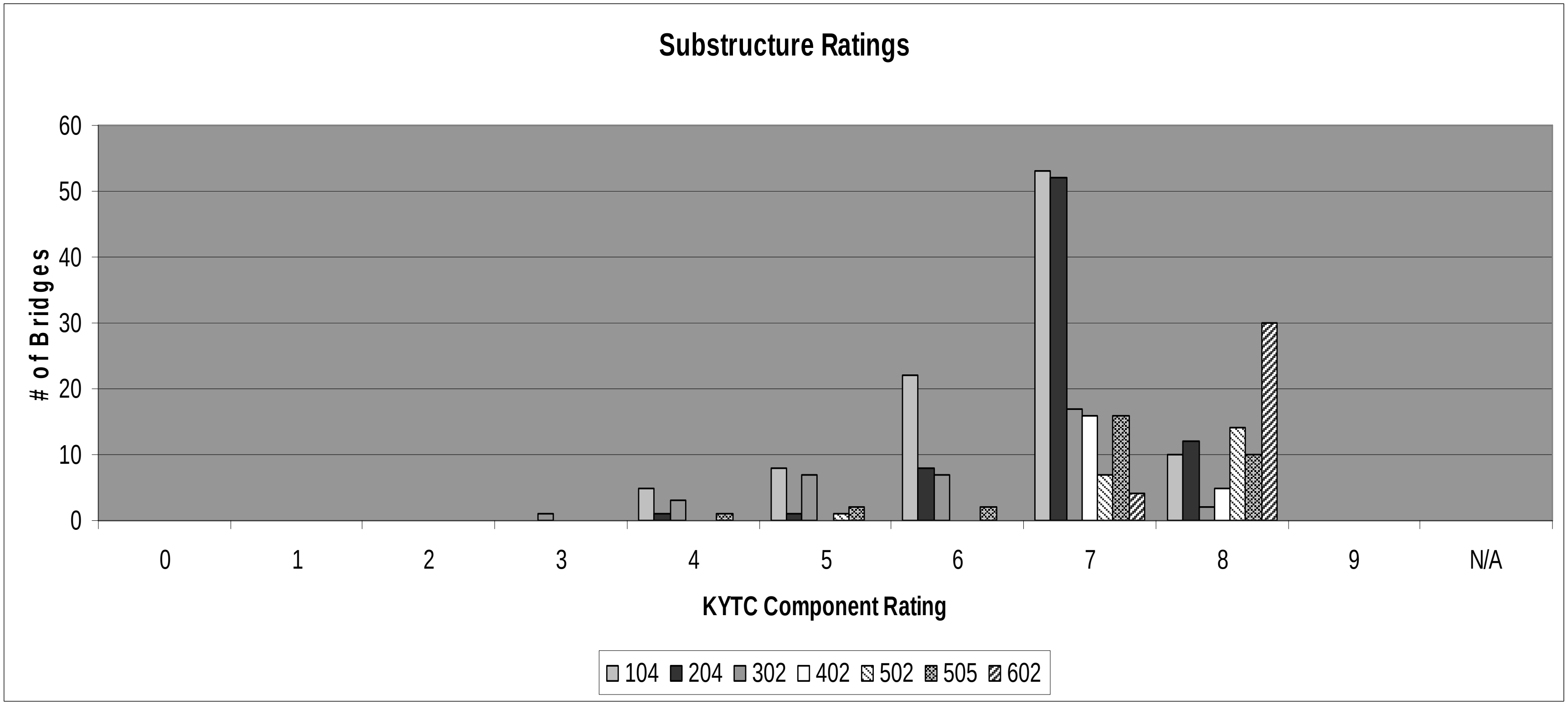

Figure 13. Avg. Overall Substructure Condition Ratings v. Number of Bridges by Category of Bridge Types Inspected.

Figure 14. D-Cracking in Concrete at the Edge of an Unarmored Deck Joint.

Figure 15. Damaged Armored Edge and Broken Joint Seal.

Figure 16. Stain on Pier Cap from Leaking Deck Joint Indicating the Seal is Not Watertight.

Figure 17. Leaking Joint (Compression Seal) with Corrosion at Steel Girder Ends and Pier Cap Staining.

Figure 18. Another View of Pier Cap in Figure 16 Showing Severe Spalling/Cracking under Bearing Plate Due to Joint Leakage.

Figure 19. Compression Seal on Deck Joint in Good Condition.

Figure 20. Bridge Deck Overlay with Silicon Seal in Good Condition.

Figure 21. Segmental (Plank) Seal in Fair to Good Overall Condition.

Figure 22. Corrosion of Steel and Debris Build-up under Open Finger Dam/Trough on Span 1 of the Riverside Parkway (1998).

Figure 23. Steel under Modular Joint in Good Condition on Span 2 of the Riverside Parkway (1998)

Figure 24. Modular Expansion Joint on the US-25 Bridge over the Ohio River at Covington in Good Condition (2001).

Figure 25. Compression Seal Becoming Dislodged from Armored Edges of Joint.

Figure 26. Compression Seal Joint with Debris Build-up.

Figure 27. Compression Seal Completely Dislodged and Non-Functional.

Figure 28. Typical Pier Cap Deterioration from Leaking Joint on Type 104 Bridges.

Figure 29. Crack in New Jersey Barrier Wall about 5 ft. from Barrier Wall Joint (Arrow).

Figure 30. Efflorescence (Vertical White Stripes) on Outside Face of Barrier Wall from Concrete Cracks.

Figure 31. Epoxy Sand Seal Weathered Away Along Gutter Line.

Figure 32. Weathered Concrete Tint.

Figure 33. Rocker with Excessive Tilt

Figure 34. Partially Blacktopped Approach Slab in Good Condition.

Figure 35. Deck with Latex Overlay in Very Good Condition.

Figure 36. Typical Stub Abutment on Aggregate Stabilized Embankment.

Figure 37. Type 104 Bridge with End Diaphragms Cast Integral with Beams.

Figure 38. Erosion at the Base of an Abutment.

Figure 39. Type 602 Bridge with Galvanized Stay-In-Place Forms in Very Good Condition.

Figure 40. Small Pipe Drain Previous Clogged with Debris.

Figure 41. Galvanized Guardrails in Very Good Condition on Type 505 Bridge.

Figure 42. Jointless 600 ft. Approach Span on Bridge over the Tennessee River in Nashville.

Figure 43. Poured Asphalt Joint on Russian Bridge.

Figure 44. Sliding Plate Joint on a Russian Bridge.

Figure 45. Spout of Trough under the Poured Asphalt Joint Shown in Figure 43.

Figure 46. Trough under Sliding Plate Joint Shown in Figure 44.

Figure 47. Paved Drainage Ditch Leading Down to Embankment on Russian Bridge.

Figure 48. Precast Drainage Ditch Running from End of Bridge to Receiving Waterway on Russian Bridge.

Figure 49. Precast Stairs for Facilitating Access to Substructure and Superstructure on Russian Bridge.

Figure 50. Integral Abutment on Bluegrass Parkway Bridge over the Chaplin River in Nelson County.

Figure 51. Polymer Asphalt Overlay on Steel Bridge Deck in Russia.

Figure 52. Concrete Cracking on Latex Overlay Bridge Deck.

APPENDIX 1 – A Commentary on KYTC Options for Bridge Management

The Condition of KYTC Bridges

Bridges are either acceptable by current design standards and provide levels of service consistent with the roadways they carry or they are substandard (deficient). Deficient bridges are either functionally obsolete or structurally deficient. Functionally obsolete bridges no longer meet current design standards. Those bridges possess inadequate load capacities, undesirable (e.g. narrow) deck geometries, insufficient under/over clearances and/or waterway adequacy problems. Structurally deficient bridges can have significant deterioration or low load ratings.

The KYTC inventory of bridges compares favorably to national bridge data of other transportation agencies. Of the 590,984 bridges in the United States in 2001, about 14 % of the national bridge inventory was structurally deficient and 21 % was functionally obsolete. Of the 280,174 bridges owned by state transportation agencies, 23 % of those were either structurally deficient or functionally obsolete. Based upon 2001-02 data, KYTC owned/maintained 9,261 bridges. An addition 4,518 bridges on the KYTC inventory were owned/maintained by local governments and others. In 2001-02, KYTC possessed 296 structurally deficient bridges (3.2 %) on the state primary system and 231 structurally deficient bridges (2.5 %) on the state secondary system. KYTC possessed 1,691 functionally obsolete bridges (18.2 %) on the state primary system and 512 functionally obsolete bridges (5.5 %) on the state secondary system. The KYTC-owned/maintained bridge inventory in 2001-02 was better than the national average of state transportation agencies for structurally deficient bridges but slightly worse for functionally obsolete bridges. Of the bridges involved in this study that were still in service in 2004, 2 % were structurally deficient and 9 % were functionally obsolete.

It should be noted that the *overall* KYTC inventory for the 7 bridge types involved in this study has remained relatively constant since 1998 with a slight increase in the total number of bridges from 6,476 to 6,600 (1.8 %). This change probably accounted for the replacement of other bridge types (small trusses) and construction of bridges on new routes. The current KYTC bridge inventory indicates that the total number of state-owned bridges has remained relatively unchanged from 2001-02 at 9,189 structures.

The bridges included in this study represent a wide range of service types (e.g., highway-waterway, highway-highway, pedway-highway, railway-highway, etc.) on a variety of routes ranging from interstates to unclassified. They are located in both rural and urban locations. They also serve a wide range of traffic ranging in ADTs from 100 to over 50,000. They exclude major river crossings. The only skewing of the data is that the bridge sampling was restricted to counties in Central Kentucky and the bulk of those were located in KYTC District 7. KTC researchers believe the data provided in this study is representative of the remaining bridges of these 7 bridge types that constitute most of the KYTC bridge inventory.

There was a significant decrease in average condition ratings of major components of the 7 bridge types included in this study over a period of only 8 years. Condition ratings of **all** components decreased; some dropping over one complete rating point. Not only do these bridges represent a majority of KYTC structures, but as deck-girder bridges, they probably should represent the most durable bridge types. Another factor is the distribution of bridges by material in Kentucky. Figure 1 shows the distribution of bridges by major material in the United States. Approximately one-half of all bridges are classified as *reinforced concrete* or *prestressed concrete* with *steel* accounting for about 40 % of the total (most of the remaining 10 % being classified *timber*). Figure 2 shows the distribution of bridges by major material in Kentucky. *Reinforced concrete* and *prestressed concrete* bridges constitute about three-quarters of Kentucky bridges. Steel bridges account most of the balance followed by timber structures with a few %. Taking into account that nearly all Kentucky *steel* bridges include major components made from concrete including decks, abutments and piers, it can concluded that the bulk of the structural material used in Kentucky bridges is some type of reinforced or prestressed concrete. In considering the condition rating decreases for the 7 bridge types, KTC researchers have concluded that those decreases are primarily due to concrete deterioration (spalling, cracking and possibly crumbling if it is considered a separate deterioration mechanism from spalling).

About 70 % of the bridges inspected under this study have service lives exceeding 25 years. If they follow the typical deterioration patterns for highway elements such as roads, in the future they will deteriorate at a faster rate and will be much more difficult and expensive to repair. Eventually, a point will be reached where KYTC will face the need to perform expensive repair/rehabilitation actions on many of those bridges or replace them.

Options for Addressing Bridge Deterioration

There are four options to manage deterioration-related bridge conditions: 1) replacement, 2) rehabilitation, 3) preventive maintenance (preservation), and 4) “do nothing” (or deferred maintenance). The best practice is to use each option for its intended purpose and not to overemphasize one while underutilizing the others. Ideally, an overall bridge inventory management strategy for KYTC would involve setting level of service and bridge condition goals and then seeking budgets to support them. However, the practical situation may become reversed with available (insufficient) funds controlling goals. It is important to track overall inventory condition ratings and determine what policies current funding levels will support and the funding level necessary to realize the desired policies. Emergency replacement and repairs are considered special events usually occurring outside the scope of normal bridge deterioration. Emergency bridge actions are usually prompted by acts of nature (floods, earthquakes, etc.) or accidents (vehicle or barge collisions).

The Texas DOT (TxDOT) groups options 1 to 3 under the terms **Major Maintenance**, **Preventive Maintenance**, and **Routine Maintenance** (1). Under **Major Maintenance**, TxDOT includes rehabilitation, reconstruction and replacement. Under **Preventive Maintenance**, TxDOT includes cleaning and painting, deck protection and joint work. Under **Routine Maintenance**, TxDOT includes repairs of decks, superstructures, and substructures, approach slabs, joints, spot painting and installation of temporary bridges.

Currently, KYTC is implementing a bridge-management system (BMS) to provide decision support for KYTC maintenance managers. It is anticipated that the KYTC BMS will accommodate the four condition-related management options, structure degradation issues (types/rates of deterioration), and KYTC actions to address them along with budgeting, user and owner requirements. It is also anticipated that the BMS will provide both network and project-level decision making. In the past, KTC researchers provided KYTC with an optimization algorithm to determine what combination of bridges could be replaced or rehabilitated providing the greatest user benefits for a given funding level (2).

Replacement

KYTC estimated costs (from 2001-02 data) for replacing all the substandard bridges it owned (i.e. those that were functionally obsolete and structurally deficient) would total $737 million. Based upon Bridge Replacement and Rehabilitation Program expenditures on KYTC bridges for 2001 and 2002 (approx. $45.7 million and $51.9 million respectively), it would take 14-16 years to replace all of those bridges. At those rates of expenditure, KTC researchers estimate that it would take 55-60 years to replace *all* KYTC-owned bridges assuming a current total inventory replacement cost of about $2.8 billion. In reviewing the KYTC estimates for substandard bridge replacement, they question whether those costs included approach realignment/improvement. If structures are replaced, typically alignment deficiencies are corrected as part of the bridge replacement cost. Roadway realignment (including earthwork and paving) costs can easily exceed those for structure replacement.

Considering just structure replacement costs for the bridges in this study that remained in service in 2004, it would cost about $2 million to replace the structurally deficient ones and about $5.8 million to replace those that were functionally obsolete (assuming a replacement cost of $75 per square foot of deck area). It would cost about $ 104 million to replace all of the bridges included in the study still in service in 2003. Expanding that for all KYTC bridges in the 7 bridge types on %age basis, based on the current KYTC inventory, the total estimated replacement cost for those structures is about $2.35 billion. KTC (or railroad lines) retired 28 bridges included in this study over an 8-year period (about 3.5 bridges per year). If that replacement rate is typical, it would take 83 years to replace the bridges in this study that were still in service in 2004.

KTC researchers believe that most of the 291 structures investigated in this study that are still in service are better candidates for maintenance options other than replacement. In the District 7 General Maintenance Forms for the bridges inspected in this study, KYTC inspectors recommended the replacement of 10 Type 104 and 7 type 302 bridges. KYTC inspectors had recommended replacement of some bridges on General Maintenance Forms dating to the 1980s. Currently, the FHWA guidelines allow the use of Highway Bridge Replacement and Rehabilitation Program (HBRRP) funds for replacement of bridges with sufficiency ratings equal to or less than 50. Only 5 of the remaining 291 bridges inspected by KTC in this study were eligible for replacement under those guidelines. Those bridges had a total replacement cost of $1.83 million.

The replacement option is implemented to remove bridges with both low levels of service (user costs) and unusually low condition ratings (owner costs) or to remove bridges with extensive deterioration where cost-effective rehabilitation or preventive maintenance are not feasible.

Rehabilitation

This maintenance option includes a variety of actions such widening, strengthening, embankment stabilization, approach revision, earthquake-proofing, and repair/ replacement of barrier walls, decks, superstructures, and substructures (or elements thereof).

Currently, the FHWA guidelines allow the use of HBRRP funds for rehabilitation of bridges with sufficiency ratings equal to or less than 80. Of the remaining 291 bridges inspected by KTC in this study, 111 were eligible for rehabilitation under those guidelines. Those bridges had an estimated total rehabilitation cost of $8.5 million (based upon 20 % of their estimated total replacement cost of $42.8 million). In addition to HBRRP funds, KYTC budgeted $14 million in 2001-02 for major contract bridge repairs statewide.

KTC researchers believe that all necessary rehabilitation and preventive maintenance actions should be conducted one project/bridge at a time to limit inconvenience to motorists, ensure proper sequencing of work, and to minimize the susceptibility of each bridge to future degradation. Exceptions to this practice could be allowed if KYTC bundled projects (i.e., multiple bridges) involving specialized work such as painting or deck repairs in single contracts to achieve lower costs.

Whether bridge rehabilitation is conducted in one project or in multiple projects performed over several years, the types of rehabilitation/preventive maintenance work should be properly sequenced so follow-on actions will not have negatively impact previous ones. In the past, bridge painting operations have been followed by deck repairs resulting in damage to the paint (Figure 3). In other cases, proper sequencing has been employed – maintenance painting has been postponed to accommodate deck work and joint repair (e.g. I-65 Expressway in Louisville). Even if proper sequencing is used, care must be taken to prevent one repair from negatively impacting follow-on work (i.e., concrete slobber from pouring deck concrete spilling onto underlying steel superstructure elements and interfering with follow-on painting of the steel).

If possible, rehabilitation work should include steps to remove problem elements such as deck joints or replace open joints with closed joints and troughs. Currently, the KYTC Division of Bridges is removing deck joints at every opportunity. Several approaches are used: 1) removing sections of deck with joints and replacing them with reinforced sections with no joints and 2) placing a new slab with no joints on top of the existing slab. In some cases, construction joints in decks leak damaging underlying elements and/or causing unsightly rust staining. Those problems need to be identified by bridge inspectors and actions taken during rehabilitation to eliminate the problem. Deck rehabilitation efforts should become more focused on low-cost methods such membranes and polymer overlays for low-volume roads. Those can be quickly installed and repeatedly replaced/renewed. Joint repair will also reduce the probability of deterioration of underlying bridges members. Painting/sealing of elements underlying joints will make them more resistant to damage from leakage.

The rehabilitation option is implemented to correct bridge deficiencies (user costs) and deterioration (owner costs) while preserving most of an existing structure. Rehabilitation work can be conducted in conjunction with some preventive maintenance actions, but it should not serve as a substitute for preventive maintenance.

Preventive maintenance (preservation)

In 2001-02, each KYTC District was provided with $1 million for maintenance and in-house repairs of bridges on the State Primary System. An additional $300,000 was provided for similar work on the State Secondary System. Bridge maintenance can be classified in two types:

operational maintenance and preventive maintenance. Operational maintenance is performed to provide proper service by bridges (user benefits) by actions such as wedging approaches and blacktopping (not overlays which constitute a rehabilitation action). Preventive maintenance actions primarily maintain and extend bridge component conditions (e.g. painting and joint repair). Some maintenance actions such as deck patching, drain clearing and brush cutting can be classified both operational and preventive maintenance.

In reviewing the District 7 General Maintenance Forms for the bridges investigated in this study, KTC researchers observed that KYTC inspectors recommended repairs of concrete distress (i.e., rehabilitation), but did not address any preventive maintenance actions (i.e. painting or sealing concrete, filling cracks and patching spalls -- other than deck patching). Currently, those are not in the toolkit of KYTC preventive maintenance actions. KTC researchers believe that KYTC needs to emphasize preventive maintenance actions that will preserve concrete. Not only should KYTC adopt concrete preservation treatments, but also it should employ them on a large number of bridges to significantly improve the durability of the entire KYTC bridge inventory.

The *NEVADA MILEPOST* (3), the Nevada transportation technology transfer newsletter, provided recommendations for preventive maintenance of bridges that should be performed periodically (e.g., annually):

- cleaning decks, seats, caps and salt splash zones;
- cleaning drainage systems;
- cleaning expansion joints;
- cleaning gusset plates of truss bridges;
- cleaning and lubricating expansion bearing assemblies; and
- sealing concrete decks or substructure elements.

The newsletter recommended other maintenance actions that should be performed when inspectors indicate that it is needed including:

- resealing expansion joints;
- spot painting steel members;
- placing of deck overlays;
- extending or enlarging deck drains; and
- removing debris from channels.

The article identified the three maintenance activities that it considered to provide the “biggest bang for the buck”:

- sealing or replacing leaking joints;
- overlaying decks; and
- spot painting.

KYTC personnel need to evaluate the condition of existing concrete before implementing any repairs or maintenance. Concrete preservation treatments include sealants discussed above under Study Advisory Committee Concerns (deck sealants), crack fillers, and patching materials/fillers. Salt-ponding tests on concrete slabs have shown that 80 % of reinforcement corrosion can occur at sites exposed by concrete cracking. Crack injection with polymers is an effective way to eliminate that problem (4). Patching materials can fill potholes and cavities created by spalling. On decks, they can provide a suitable base for polymer and membrane overlays and can prevent the reoccurrence of reinforcing steel corrosion that initiated a spall. Other preventive maintenance actions that need to be investigated include chloride removal and cathodic protection. Those have been applied to both bridge decks and substructure elements. System costs and maintenance upkeep need to be evaluated to determine whether those approaches are practical for KYTC.

Standardized guidelines need to be established for follow-on decisions/repairs based upon the evaluations by KYTC personnel. The Ohio DOT is currently developing web-based bridge maintenance manual containing repair guidelines (5). As shown in Appendix 1, the Michigan DOT (MDOT) has bridge deck repair guidelines in place (6). The proposed guidelines would follow the MDOT format. They would promote the application of consistent maintenance decisions/actions in all KYTC Districts.

Other preventive maintenance actions such as painting and joint repair need to be employed on a more widespread, proactive basis. Spot painting should be employed to protect distressed areas on bridges where most of the existing paint is in good condition. Spot painting will provide corrosion protection and prevent structure loss-of-section that might require more expensive repairs. Current funding for maintenance painting is insufficient to establish or maintain a sustainable painting cycle (where the number of bridges painted is sufficiently great to allow repainting of all structures within 20-30 years). Joint repair can be employed as a preventive maintenance action if a bridge does not warrant other deck-related rehabilitation actions. Poured silicon should be used in place of asphalt to obtain better performing joint seals. The threshold criteria for joint repair should be leakage, not obvious mechanical damage. Purvis recommends a proactive deck joint program including: 1) washing (cleaning) decks, 2) keeping drains open, 3) removing debris from joints, and 4) fixing small joint/seal problems before they become big ones (7). KTC researchers believe that most deck drains will perform acceptably if the decks are cleaned annually and any clogged drains are cleared. Some drain outlets need to be extended to avoid outflow that impinges on bridge elements (Figure 4).

INDOT has a unique program whereby HBRRP funds are now used for preventive maintenance. Each of the 6 INDOT Districts can get up to $ 500,000 for contract preventive maintenance funding. Currently, three INDOT Districts are participating in this program. District bridge inspection personnel prepare the contracts for work such as joint, approach and deck repair. This effort has produced tangible benefits in reducing the amount of bridge rehabilitation work as a result of preventive maintenance and a fourth INDOT District will come on line with the program this fiscal year. For an average preventive maintenance expenditure of about $18,000 per bridge, INDOT has been able to defer extensive rehabilitation work on bridges for 9-10 years (8).

The Pennsylvania DOT has compiled a list of cost-effective treatments that it believes will provide the greatest benefit in maintaining bridges (9). Those include:

- eliminating deck joints in old bridges;
- repairing or installing new expansion dams on bridge decks;
- repairing old bridge decks;
- maintaining proper deck drainage;
- repairing or replacing deck approach slabs;
- repairing beam ends and beam bearing areas; and
- bridge painting.

Some of those actions relate to large-scale repairs that should be considered rehabilitation actions.

Preventive maintenance can be performed by KYTC District forces or by bundling projects in contracts to firms with specialized equipment and skills that can perform specific maintenance actions (painting, sealing, crack-filling or joint repair/replacement).

In 2002, FHWA revised the HBRRP regulations permitting the use of those funds for preventive maintenance (10). FHWA officials enacted that step to temporarily extend the lives of bridges in a state transportation agency's inventory until funds eventually became available for their replacement (11).

The preventive maintenance option typically will not significantly improve bridge element condition ratings nor will it address user costs. It will address owner costs by extending the service lives of bridges before replacement or additional work is required.

"Do nothing" (deferred maintenance)

The "do nothing" or deferred maintenance option entails no significant work on a bridge, perhaps other than annual or minor operational maintenance and routine inspections. It provides the least cost and the greatest long-term risk for unfavorable consequences. This option is important in that it postpones work on a structure while subjecting it to years of normal service and aging. The funding saved in applying this option can be applied to other bridges. During this period, bridges in the KYTC inventory subjected to this option must be capable of providing acceptable service and sustaining minimal degradation due to normal service and environmental exposure. The deterioration in KYTC bridge condition ratings for the 7 bridge types discussed previously indicates that is currently not the case. Additional steps must be taken to limit degradation prior to the "do nothing" period between initial construction or the last rehabilitation/preventive maintenance work to extend the interval before follow-on maintenance activity becomes necessary. If a bridge or bridge component is to be eventually removed from service, operational (sunset) maintenance such as blacktopping can be performed enabling the bridge to provide acceptable service until rehabilitation or replacement funds become available.

Preservation Aesthetics

Nationwide, bridge maintenance encompasses many needs addressed by insufficient funds. Aesthetics rarely impacts bridge maintenance unless maintenance painting is involved. Then, community (stakeholder) interests come into play. Another situation involves graffiti, especially on urban bridges (Figure 5). Graffiti is seen as the onset of neighborhood decline and increased crime. The elimination of graffiti is usually left to local governments that typically (and repeatedly) attempt to remediate graffiti by covering it with paint. The result is usually as unsightly as the graffiti. KYTC can discourage graffiti by employing graffiti-resisting coatings on bridge steel and concrete. Currently, KTC is researching anti-graffiti coatings for concrete and will have some viable systems and application methods by 2006.

Bridges in or near populated areas or overpass structures on highly traveled roads need such coatings to repel graffiti and/or facilitate its removal. Other forms of aesthetic/structure distress may make bridges in the public view appear shabby or dilapidated (Figure 6). That does not reflect positively on agency stewardship and in those special cases, aesthetic considerations may drive maintenance actions

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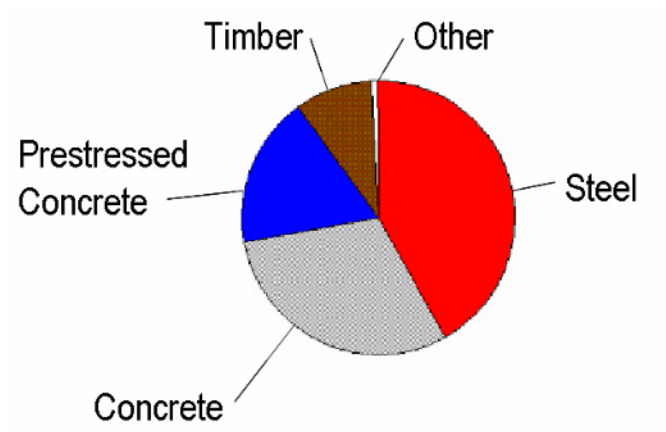

Figure 1. Distribution of Bridges in the U.S. by Classification/Major Structural Material.

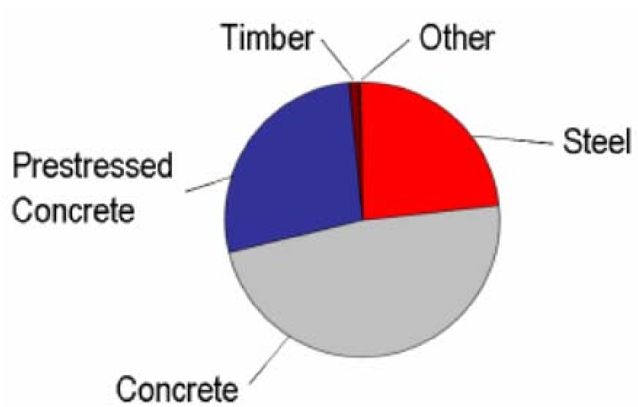

Figure 2. Distribution of Bridges in Kentucky by Classification/Major Structural Material.

Figure 3. Bridge Overcoating (Painting) Damaged by Follow-on Deck Work.

Figure 4. Short Drain Outlet Resulting in Damaged to Concrete Beam.

Figure 5. Graffiti over Previous Remediation (Gray Paint) on Pier Column of Urban Bridge.

Figure 6. Bridge Appearance with Negative Impact to the Surrounding Community.

APPENDIX 2 – Michigan DOT Bridge Deck Repair Matrix

BRIDGE DECK REPAIR MATRIX USER GUIDELINES

This matrix is a tool for Bridge Engineers to use in the selection of deck repair options. The condition of the deck is usually the driving force, or the key indicator, leading to a structure being considered for rehabilitation or replacement. However, there are times when other issues affecting the bridge may elicit the need for a rehabilitation project and this matrix does not address those situations. Some of these situations are superstructure deterioration, sub-structure deterioration, and functional issues such as under-clearance and/or bridge width. Sometimes it is desirable for an entire corridor to be brought up to a specific condition level as part of an overall strategy. So the user is cautioned to interpret the information from the matrix in the context of each specific case and use engineering judgment.

The matrix can be used from left to right or from right to left. If you have scoping inspection data with a deck delamination survey, select the row in the left column that matches the % of surface defects. Then select the row in the second column that matches the % of underside defects. To the right of this you will find a repair option and the associated changes to the NBI and the expected service life of that repair.

If you are looking for a fix that will last for a given period of time, select a row from the right column that matches the length of service desired and scan to the left to find the repair option. Be advised that the condition of the bridge at the time of the rehabilitation effects the expected service life of the selected repair option. So if the structure is in worse condition than shown on the left side of the matrix, the repair will not last as long. Conversely, if the deck is in better condition than shown on the left, a longer service life could be expected.

This matrix has been constructed based on the best knowledge of individuals from Construction & Technology, Maintenance, and Design Divisions, and FHWA with many years of experience working with bridges. When used in conjunction with the Bridge Inspection Report and Bridge Project Scoping Report, the matrix can be an accurate guide in the majority of situations and will lead to a repair option that is economical and consistent with the Departments goals.

BRIDGE DECK REPAIR MATRIX

CONDITION STATE		REPAIR OPTIONS (3)	POTENTIAL RESULT TO NBI		NEXT ANTICIPATED EVALUATION
Deck Surface Deficiencies (1) **NBI # 58a**	Deck Underside Deficiencies (2) **NBI # 58**		Item # 58a Deck Surface	Item # 58 Overall Deck Rating	
N/A	N/A	CSM Activities	No Change (5)	No Change (5)	1 to 8 years
2% to 5% NBI = 5 & 6	< 5% NBI > 5	Deck Patch / Seal Cracks/ Polymer Overlay (4)	Up by 1 pt.	No Change (5)	1 to 8 years
	> 5% NBI < 5	Deck Patch	Up by 1 pt.	No Change	1 to 8 years
		Hold	No Change	No Change	3 to 10 years
5 % to 15% NBI = 5	N/A	Hold	No Change	No Change	3 to 7 years
15% to 30% NBI = 4 & 5	< 5%, NBI > 5	Deep Concrete Overlay	Up by 3 pts.	Up by 1 or 2 pts.	25 to 30 years
	5% to 30% NBI = 3, 4, or 5	Shallow Concrete Overlay	Up by 2 pts.	May or may not Change.	10 to 15 years
	> 30% NBI = 2 or 3	Asphalt Overlay (6)	Up by 2 pts.	No Change	8 to 10 years
> 30% NBI = 3 or 4	< 5%, NBI > 5	Deep Concrete Overlay	Up by 3 pts.	Up by 1 or 2 pts.	20 to 25 years
	5% to 30% NBI = 3, 4, or 5	Shallow Concrete Overlay	Up by 2 pts.	No Change.	10 years
		Asphalt Overlay (6)	Up by 2 pts.	No Change	5 to 7 years
	> 30% NBI = 2 or 3	Replace Deck	NBI now 9	NBI now 9	40+ years
		Bituminous Cap (7)	NBI now 7 or 8	No Change	1 to 3 years

1.) % of deck surface area that is spalled, delaminated, or patched
2.) % of deck underside area that is spalled, delaminated, wet, or map cracked.
3.) The “Do Nothing” option or “Hold” option implies that there is on going maintenance of filling potholes with cold patch and scaling of incipient spalls.
4.) Polymer overlays should only be used when the deck has very little deterioration.
5.) Sustains the current condition longer.
6.) Asphalt overlay with waterproofing membrane. Deck patching required prior to placement of waterproofing membrane.
7.) Bituminous cap without waterproofing membrane for ride quality improvement. Deck must be replaced in 1 to 3 years.