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16. Abstract The objective of this report is to provide a guide for evaluating bridge decks. This report was developed under the research project titled: "Development of a procedure for efficient evaluation of bridge decks". During the research, the degradation process ongoing in bridge decks due to service time was analyzed. Investigation was based on inspection of many bridge decks, review of data from the Bridge Inventory Database, and finite element modeling. For the finite element models, parameters influencing deterioration of concrete deck slabs were investigated and included in degradation and failure scenarios. This report is to be used as a supportive document to the many guidelines and specifications either developed or recognized by Michigan Department of Transportation, such as the FHWA's Bridge Inspectors Training Manual/90, NHI course 13055, "Safety Inspection of IN-Service Bridges", MDOT's PONTIS Bridge Inspection Manual, Michigan's Structural Inventory Database, and Michigan's Bridge Repair Matrix.					
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# MICHIGAN DECK EVALUATION GUIDE

**Report submitted to  
The Michigan Department of Transportation**

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## 1. INTRODUCTION

Bridge decks are an important part of Michigan's transportation system. They carry traffic over rivers and highways, and they protect the load carrying components of the bridge beneath them. Many of Michigan's bridges were built in 1950's and 1960's, and their decks are now in need of rehabilitation or replacement. Often, the first component of a bridge to deteriorate is the bridge deck, since it is directly exposed to the environment, traffic loads, and deicing salts. The overwhelming majority of Michigan's bridge decks are reinforced concrete slabs on girders. In order to best allocate the States resources and funds, bridge engineers and inspectors need to be able to correctly evaluate and predict the remaining life of bridge decks. With this understanding, the objective of this report is to provide a guide for evaluating bridge decks.

This report was developed under the research project titled: "Development of a Procedure for Efficient Evaluation of Bridge Decks". During this research, the degradation process ongoing in bridge decks due to service time was analyzed. Analysis was based on inspection of many bridge decks, review of data from the Bridge Inventory Database, and finite element modeling. For the finite element models, parameters influencing deterioration of concrete deck slabs were investigated and included in degradation and failure scenarios.

Many of the tools bridge engineers and inspectors need to be familiar with are either shown in this report, or they are referenced. This report is to be used as a supportive document to the many guidelines and specifications either developed or recognized by MDOT (Michigan Department of Transportation), such as the FHWA's Bridge Inspectors Training Manual/90, NHI course 13055, "Safety Inspection of In-Service Bridges", MDOT's PONTIS Bridge Inspection Manual, Michigan's Structural Inventory database, and Michigan's Bridge Repair Matrix.

## **2. BRIDGE DECKS IN MICHIGAN – A HISTORICAL PERSPECTIVE**

The information about changes in the MDOT Bridge Design Manual, which were made in the last 25 years can be helpful in field inspections, evaluation of the deck deterioration level, and to better understand degradation processes in the structure. The design of concrete slabs has been performed according to the Michigan Department of Transportation Bridge Design Manual. Over the years, the Manual has been changed to include special provisions aimed at prevention of early deterioration of reinforced concrete. Each important change related to concrete deck slab in bridges was recorded in an Informational Memorandum issued by the Engineer of Design. They are summarized below in a chronological order.

The oldest existing concrete bridge decks in Michigan were constructed in 1920's using square reinforcing bars and concrete with  $f'_c$  of about 10 MPa. The square bars were replaced with round bars in 1930's, and then deformed bars in 1940's.

In 1964, for bridge decks incorporating continuous steel beams, it was recommended to take advantage of composite action in the positive moment area.

In 1967, it was decided to use reinforcing steel based on 20 ksi (140 MPa).

In 1967, it was required to use boiled linseed oil as a protective treatment on all concrete surfaces on the bridge deck between the fascia lines. In 1989 it was decided stop using this protective treatment.

Other changes were related to concrete. Since November 1980, latex overlays were used on some new bridge decks. In 1972, it was decided to apply an additional 0.5" of concrete cover over the top reinforcing steel of bridge decks. In December 1975, a clear cover over the top mat of reinforcement was increased to three inches (75mm), and 1.5" (37mm) for the lower mat.

A major factor in the development of Michigan bridge decks was the introduction of epoxy coated reinforcing bars. Starting in 1975, it was required to use the epoxy coated reinforcement in the top mat of all bridge decks. In general, prior to that year only uncoated bars were used in bridge decks. The next change in the Bridge Design Manual made in April 1980, directed to use epoxy coated reinforcement in the traffic facing side of the traffic barrier. Later the same year, the use of epoxy coated bars was extended to the top and bottom mats of all bridge decks, and from December 1980 all superstructure reinforcing steel had to be epoxy coated for corrosion protection.

Starting in 1980, a “sandwich” construction was specified, with 1.5” (38mm) concrete plus 1.5” (38mm) modified latex concrete, for structures carrying freeways over an obstruction and freeways in urban areas with ADT exceeding 1,000 vehicles. “Monolithic” construction with 3-inch (75mm) concrete cover was specified for freeways in rural areas. In 1983, two stage construction with latex concrete was discontinued, except of bridges in metropolitan areas with ADT’s exceeding 50,000.

In 1989, it was decided to make bridge spans continuous wherever possible, to reduce the number of deck joints.

In 1996, it was required to pour all bridge decks at night.

In 1997, a special provision was added allowing the option of using silica fume (microsilica) concrete or latex modified concrete on bridge overlay projects.



### 3. FORMS OF DECK DETERIORATION

Concrete decks are subject to deterioration, which may lead to premature need for repair or replacement. Many different factors influence the condition of a bridge deck. The main causes of deterioration include:

- poor material properties (concrete mix) resulting in lower material durability, shrinkage, scaling and other problems,
- inadequate pouring procedures (lack of construction joints),
- inadequate curing (moisture conditions),
- freeze and thaw cycles,
- truck load spectra (axle loads and groups of axles),
- corrosion of reinforcement,
- fatigue and degradation of steel and concrete due to repeated cycles of strain/stress.

The ACI Manual of Concrete Practice, Part 1, Ch.3, ACI 201.1R-98, *Guide for Making a Condition Survey of Concrete in Service*, gives definitions for kinds of distress manifestations to help standardize the reporting of the condition of concrete. Short definitions of various types of distress are given at the beginning of the next chapters, which describe the defects and degradation processes that occur on Michigan's bridge decks.

The major forms of deterioration include cracking of concrete, spalling, potholes, delamination, carbonation, corrosion of reinforcing steel, and destruction of deck joints.

### 3.1 Cracks

#### Definitions:

*Carbonation of concrete* – A reaction, which occurs in concrete exposed to carbon dioxide, and that produces carbonates. This process is accompanied by shrinkage.

*Crack* – A complete or incomplete separation of concrete into two or more parts produced by breaking or fracturing.

*Craze cracks* – Fine random cracks or fissures in the surface of mortar or concrete, Figures 3-1, 3-2.

*Diagonal crack* – In a flexural member, an inclined crack caused by shear stress, usually inclined at about 45 degrees to the vertical axis; or a crack in a slab, not parallel to either the lateral or longitudinal directions, Figures 3-12, 3-13, 3-14..

*Pattern cracking (Map cracking)* – Cracking in the concrete in the form of a pattern; resulting from a decrease in volume of the material near the surface; increase in volume of the material below the surface, or both, Figures 3-3, 3-4.

*Shrinkage cracking* – Cracking of a structure or member due to failure in tension caused by external or internal restraints as reduction in moisture content develops, or as carbonation occurs, or both, Figure 3-5. Plastic shrinkage cracks occur when the rate of evaporation exceeds the rate of concrete bleeding in fresh concrete (which has not started to harden).

*Temperature cracking* - Cracking due to tensile failure, caused by a temperature gradient in members subjected to external restraints or by a temperature differential in members subjected to internal restraints.

*Transverse cracks* – Cracks that develop at right angles to the long direction of a member, Figures 3-9, 3-10, 3-11.

*Longitudinal cracks* – Cracks that develop parallel to the long direction of a member, Figures 3-6, 3-7, 3-8.

### Observations:

#### Transverse Cracks

Transverse cracks are the most commonly occurring type of crack. They can be initiated soon after the deck is constructed due to restrained shrinkage (NCHRP Report 380). In general, the parameters which influence the initiation of transverse cracks can be related either to the structure or to materials. The cracks occur when the longitudinal tensile stress exceeds the concrete modulus of rupture. Girder type, girder spacing and support conditions influence the occurrence of transverse cracks and the distance between them. Other variables which affect transverse cracks are: continuous spans, girder stiffness, thickness of the slab, concrete shrinkage characteristics, concrete modulus of elasticity, and temperature history at deck placement. Transverse cracks often continue across the full width of the deck.

It has been observed that smaller size reinforcing bars and a smaller spacing between them decreases transverse cracking. In continuous-span bridges, the middle spans usually have more transverse cracks; this may be caused by the increased stiffness of girders in interior spans

Traffic load can also cause transverse cracks. For some bridge geometric configurations (short span and large width) and load positions (heavy trucks in one lane), field measurements have shown that tensile stress can occur in the longitudinal direction at the top of the slab (in the unloaded lane area). The transverse crack starts at the edge of the

slab and extends to the middle of the lane. It is believed that these cracks are caused by the trucks, because shrinkage cracks typically extend through the full width of the deck.

### Longitudinal Cracks

Longitudinal cracks which run parallel to the girders occur most often in box girder bridges, along the longitudinal joints between boxes. Their occurrence is due to a non-uniform movement of the girders (the “piano effect”, which occurs without transverse ties). In the case of steel girders, the longitudinal cracks can be caused by forces induced by the diaphragms, depending on the type of diaphragm, spacing, and connection to the girders and slab. It is believed that the occurrence of longitudinal cracks can be also related to the arching action in the slab.

### Diagonal cracks

Diagonal cracks (at the angle to the axis of the slab) occur on skewed bridges in the corners, on the top of the deck and close to the slab’s construction joints. They are caused by additional stresses due to torsion in the skewed slabs.

### Pattern Cracks (Map Cracking)

Pattern cracks are oriented in random directions. They appear on the surface of the concrete in different size: fine, medium or large. They can be caused by volume changes in concrete and influence of ambient conditions (temperature and pollution).

Map cracks (small cracks oriented in different directions) are most likely caused by a combination of freeze and thaw cycles and the steel corrosion process, which can destroy the concrete cover from inside. This is a very complex phenomenon. The locally weaker concrete (more porous) allows water to penetrate to the steel rebars and to freeze. The cyclic live load will also have a more visible effect on the weaker and less dense concrete

in that part of the deck. The random pattern of map cracks confirms the heterogeneity of the concrete.

In general, the carbonation process in concrete depends on time and the amount of carbon dioxide in the air. Carbonation may result in deterioration and a decrease in the pH of the cement paste, which leads to corrosion of reinforcement near the surface. Exposure to carbon dioxide during the hardening process may affect the finished surface of the slab, leaving a soft, dusting, less wear-resistant surface. Such a porous surface can be subject to further chemical attack by deicing salt.

A visible sign of the carbonation process is pattern cracking on the deck surface, caused by alkali-carbonate reaction.



Figure 3-1. Craze cracks (top of the deck)



Figure 3-2. Pattern cracks (bottom of the deck)



Figure 3-3. Pattern cracks (large)





Figure 3-4. Pattern cracking (large)



Figure 3-5. Shrinkage cracks



Figure 3-6. Longitudinal cracks (top of the deck)

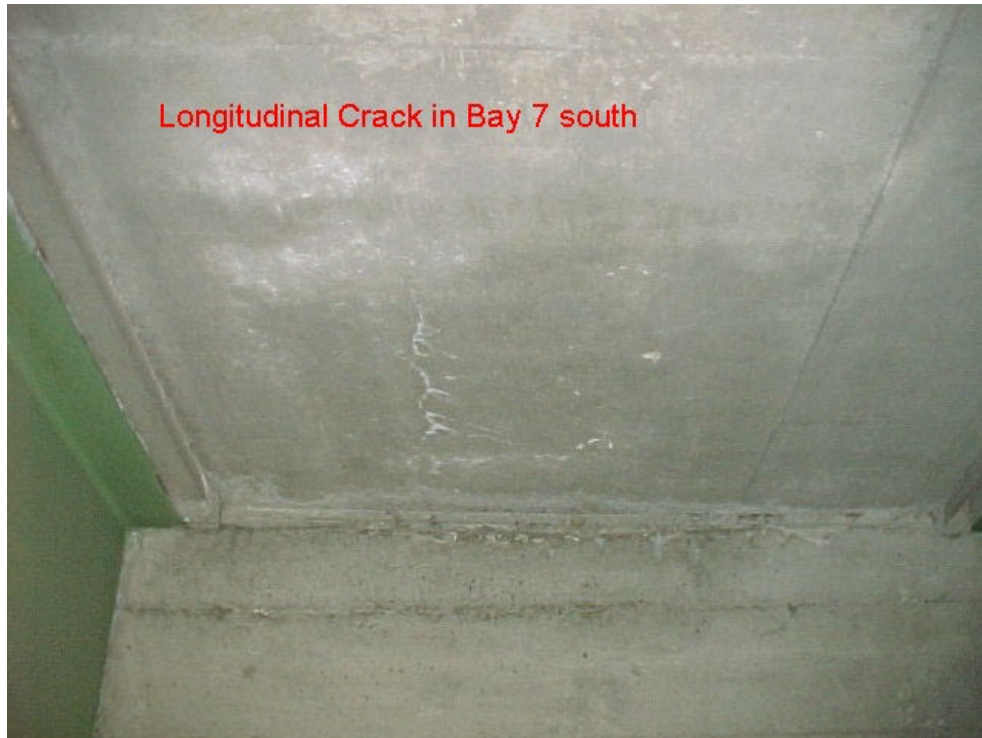


Figure 3-7. Longitudinal crack (bottom of the deck)





Figure 3-8. Longitudinal crack (bottom of the deck)



Figure 3-9. Transversal cracks



Figure 3-10. Transverse cracks, caused by restraint shrinkage



Figure 3-11. Transverse cracks (bottom of the deck), caused by restraint shrinkage





Figure 3-12. Diagonal crack close to support (bottom of the deck)



Figure 3-13. Diagonal crack close to support (bottom of the deck)



Figure 3-14. Diagonal crack close to joint (bottom of the deck)

### **3.2 Delamination**

#### Definitions:

*Delamination* – A separation along a plane parallel to a surface as in the separation of a coating from a substrate or the layers of a coating from each other, Figures 3-15, 3-16, 3-17..

#### Observations:

In Michigan, bridge decks have been overlaid with latex modified concrete since 1980. In 1994, silica fume modified concrete was approved as an alternate material for bridge deck overlays. In decks with overlays, delamination is the most common form of deterioration. It can be described as a loss of bonding between the old part of deck and a

new overlay. Delamination between the two layers can cause cracks to form in the new overlay layer under traffic loads. After the process of cracking is initiated, the material is crushed and potholes may occur in the last stage of damage. These holes are usually as deep as the overlay. Delamination can be also caused by the corrosion of the upper slab reinforcement.



Figure 3-15. Delamination





Figure 3-16. Delamination



Figure 3-17. Delamination

### 3.3 Potholes

#### Definitions:

*Disintegration* – Reduction into small fragments and subsequently into particles, Figure 3-18.

*Blistering* – The irregular raising of a thin layer, frequently 25 to 300 mm in diameter, at the surface of placed mortar or concrete during or soon after completion of the finishing operation; blistering is usually attributed to early closing of the surface and may be aggravated by cool temperatures, Figures 3-19, 3-20.

#### Observations:

There are several different types of potholes. They can be located in decks of relatively good condition, where there are no cracks and the surface quality is good. Potholes are also often observed on decks with a latex layer on top, Figures 3-23, 3-24. Because of likely delamination between the concrete slab and latex, the locally cracked upper part of the deck can be disconnected from the bottom slab and crushed by truck wheels. Such potholes usually have sharp edges perpendicular to the hole bottom.

Other potholes may start with blistering and be caused by local erosion of material. Often they are located on the line of a bigger crack, Figure 3-21. Prior to hole formation, the top reinforcement cover is cracked and disintegrated in many places by a complex influence of weather, corrosion and fatigue load cycles. Then, this highly cracked part of the material is easily crushed by truck wheels. These holes are irregular in shape, different in depth, and in some cases the top reinforcement is exposed through the hole.

Generally, the occurrence of potholes appears to be random, but it is possible to find some regularity. They are typically located in lanes which are most exposed to traffic, and quite often in the path of trucks wheels, Figure 3-22. This location indicates the



influence of traffic load, which may cause additional damage in places of local weakness (some transverse cracks or weaker concrete).



Figure 3-18. Disintegration



Figure 3-19. Blistering





Figure 3-20. Blistering



Figure 3-21. Potholes with local erosion of material, located on the line of bigger crack



Figure 3-22. Potholes following pattern of wheels



Figure 3-23. Potholes in latex overlay





Figure 3-24. Potholes in latex overlay

### 3.4 Corrosion of Reinforcement

#### Definitions:

*Corrosion* – Destruction of metal by chemical, electrochemical, or electrolytic reaction with its environment.

#### Observations:

Concrete decks are reinforced with steel bars, which are placed to resist tensile stresses. These bars are basically round in cross section with lugs or deformations rolled into the surface to create mechanical bond between the bars and the concrete. To properly evaluate any cracks in the deck caused by corrosion of the reinforcing steel, it is necessary to identify the direction of the primary bars. The support points on a multi-beam bridge are parallel with the direction of traffic. Therefore, the primary deck

reinforcement is perpendicular to the traffic direction. Because the corrosion of reinforcing steel can be an important factor in deck deterioration, Michigan began using epoxy coated rebars in 1980's. In older bridge decks, the reinforcing steel can be without protection.

The corrosion of steel bars has a dual negative influence on the deck condition. First, the corroded part of the bar destroys the bond between the reinforcement and concrete and increases concrete volume, which causes delamination and crack enlargement. The decreased section of the reinforcing steel can also decrease the capacity and stiffness of the section. An advanced corrosion process may destroy the concrete cover and expose reinforcing bars to the surface.

### **3.5 Destruction of Deck Joints**

#### Observations:

The primary function of the deck joint is to accommodate the expansion and contraction of the deck. It also seals the deck sections, and provides a smooth transition from the approach roadway to the bridge deck. To evaluate its proper functioning, it is necessary to identify the types of deck joints.

Prior to 1972, the principle bridge deck expansion joint system used in Michigan was the sliding metal plate joint. The major problem with this type of system was that the available sealants were not capable of providing a sealed joint for the movement ranges normally encountered in most structures. From 1972 to 1978 the majority of expansion joint devices installed in Michigan were metal-reinforced elastomeric pad systems. This type of system was an improvement over the sliding metal plate joint but it too had its limitations. The one-piece steel reinforced pads were bolted into a block on both sides of the joint. Each pad section was 1.2 m long. Eventually these joints began to leak between the pad sections and between the pad and the concrete seat. From 1978 to 1985 a new type of pad system was developed. These pad systems used either neoprene or aluminum

pads to hold down a continuous neoprene gland. The 1.2 m – 1.8 m pads were bolted down on top of the gland. The threaded bolts were cast into the concrete or a hole was drilled and the bolts were epoxied in. The downfall of these systems was that they did not accommodate the impact from snowplow blades. This would eventually cause the anchor bolts to loosen and the joints to leak. Sometimes the pads could be totally destroyed or removed by the snowplows.

From 1985 to the present the primary expansion joint used in Michigan is the strip seal. The strip seal systems consist of full-length steel rails with welded steel anchorage pegs that are cast directly into the concrete. The rails have a C – shaped groove milled into their inner edge to connect to the continuous neoprene seal on both sides of the joint. If these systems are installed properly, they rarely leak.

Problems with deck joints, which can be detected during an inspection, are:

- debris lodged in the joint may prevent normal expansion and contraction, causing cracking in the deck,
- the joint seal might be torn, pulled out of the anchorage, or even gone,
- if the new wearing surface is added with no regard to the joints, the transverse cracks in the overlay become the only evidence of the joint, while joint function is severely impaired,
- if the deck is not curved, the joint opening should be parallel across the deck; otherwise, it can indicate a disconnection between the joint pad or rail and the concrete slab,
- both sides of the joint should be at the same level with no vertical displacement between the two; otherwise, the impact from wheels can crush the concrete close to joint.

Examples of destruction close to deck joint are presented in Figures 3-25, 3-26 and 3-27.



Figure 3-25. Destruction of joint



Figure 3-26. Destruction close to joint



Figure 3-27. Destruction close to joint



## 4. DETERIORATION SCENARIOS

### 4.1 General Scenarios

The major parameters which affect deterioration of concrete bridge decks in Michigan include quality of concrete, traffic loads (weights, volume, pattern), weather (freeze and thaw cycles) and use of deicing agents. Quality of concrete depends on the mix (water/cement ratio) and curing conditions (temperature, humidity). In most cases, the initiation of the deterioration process is facilitated by shrinkage cracks (perpendicular to girders). Then, freeze and thaw cycles cause growth of cracks, which eventually may lead to corrosion of reinforcement. Cracked concrete is subjected to pounding forces induced by heavy trucks, causing breaking and crushing of the slab. It is clear that presence of heavy trucks is an essential factor in the deterioration process. Quite often, the pattern of potholes follows the traffic pattern (truck wheel lines). However, trucks alone are not sufficient to cause damage to the bridge deck. The triggering factor is concrete quality (shrinkage).

In traditional concrete overlays, the deterioration starts through shrinkage cracks, and it progresses depending on the quality of material as follows:

- Initial shrinkage cracks occur due to poor quality of the concrete mix, and/or poor pouring/curing conditions
- Once initiated, the freeze and thaw cycles enlarge cracks
- This may cause the corrosion of upper slab reinforcement what may in turn lead to more extensive cracks and delamination
- Portions of the slab overlay between cracks may be more vulnerable to wheel loads (heavy trucks), resulting in a considerable stress concentration and leading to material crushing
- Crushed material disintegrates and large potholes may occur.



In decks with overlays, debonding is the major problem leading to delamination. A poor connection between the overlay and deck exposes a thin layer of the overlay to large traffic loads. Thus, cracking occurs, and pounding truck wheels crush the loosened-up pieces. Sounding tests can be used to check if a bridge deck with an overlay is debonding. Cracks existing in old parts of the deck (the remaining part of the slab, when the upper layer is removed) can be reflected to the surface of the new overlay.

There are many parameters which influence the deterioration process, such as pouring conditions (temperature and humidity), ambient conditions during the service life (temperature gradients and freeze/thaw cycles), live load (with its dynamic and fatigue influences) and chemical corrosion of the concrete and reinforcement. In fact, all these parameters can occur simultaneously and they can be complementary to one another. The resulting decrease in slab stiffness not only affects its flexibility but also live load distribution to the girders. However, it has a small effect on the stiffness of the whole superstructure.

#### **4.2 Analysis of the Michigan Bridge Inventory Data**

Field inspections indicate that there is only a very weak correlation between the damage level and the duration of service. To establish such a relationship, continuous observations over a longer time period are needed (at least 5 years). However, the relationship between deck condition (rating), years of service, and ADT (Average Daily Traffic) has been established and is based on data from the Michigan Bridge Inventory (Deck Data). The database includes over 100,000 entries. The most important information is the rating factor for the deck slab, ADT, and number of years of service at the time of inspection. Over 100 randomly selected bridges were considered

The deck rating factors are plotted versus years of service at the time of inspection, for four categories of ADT:

- ADT = 1-200
- ADT = 200-1,000
- ADT = 1,000-5,000
- ADT = 5,000-20,000

It is clear that rating decreases with years of service and the decrease is faster for larger ADT. To further analyze this trend, a linear regression line was fitted for each graph for four categories of ADT. The slope of the regression line increases with increasing ADT. This confirms the detrimental effect of truck load on bridge decks. Deck ratings versus years of service for different categories of ADT are shown in Figures 4-1, 4-2, 4-3, and 4-4. Linear regression lines for deck rating versus years of service are shown in Figure 4-5. A polynomial (4<sup>th</sup> degree) was also fitted to model the data. For all ADT categories the results are shown in Figures 4-6, 4-7, 4-8, and 4-9 (with all data points). The curve confirms various stages of deck deterioration. The steep slope for the first 20 years corresponds to initial shrinkage cracking followed by freeze/thaw cycles. The plateau, and even slight increase of the rating corresponds to ongoing maintenance and repair of the deck slabs. A sharp decline after 60 years corresponds to the final stage of deck slab life, with extensive damage caused by trucks combined with freeze/thaw cycles.

The curves presented above can be used as an aid to estimate the remaining life of the deck under known loading condition (ADT) and years of service.

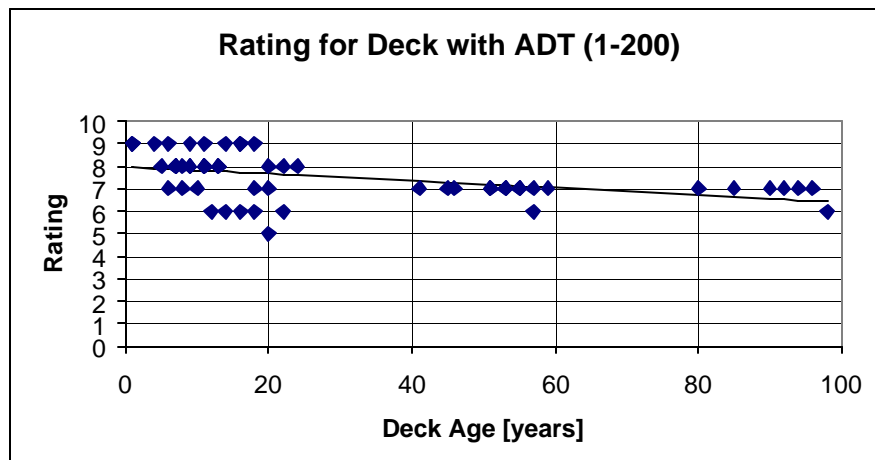


Figure 4-1. Rating for decks based on MBID (Michigan Bridge Inventory Data) (ADT 1-200).

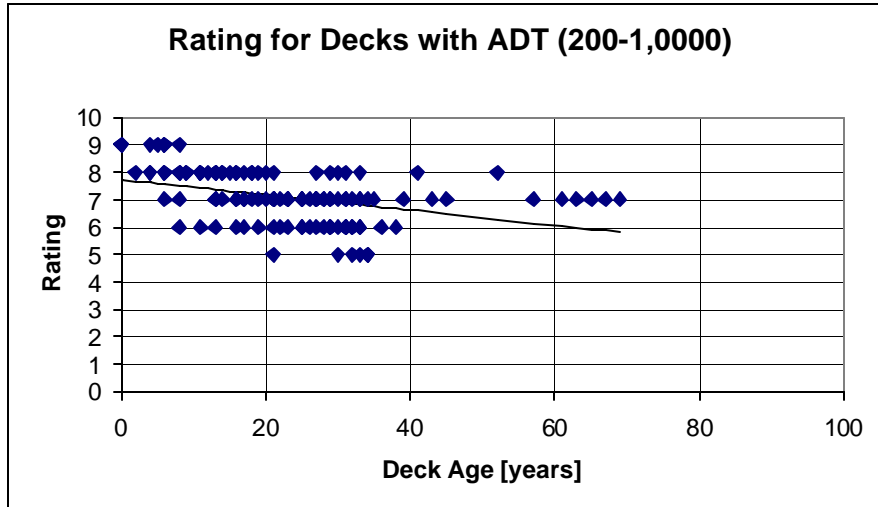


Figure 4-2. Rating for decks based on MBID (ADT 200-1,000).

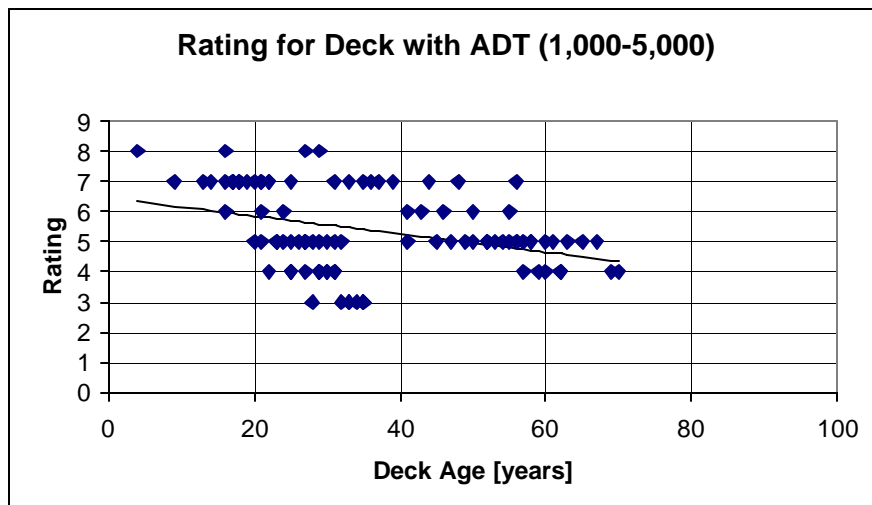


Figure 4-3. Rating for decks based on MBID (ADT 1,000-5,000).

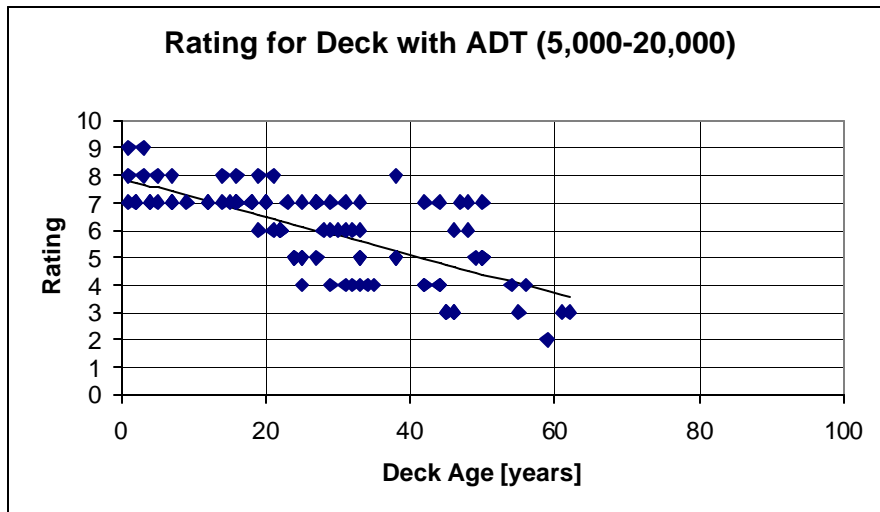


Figure 4-4. Rating for decks based on MBID (ADT 5,000-20,000).

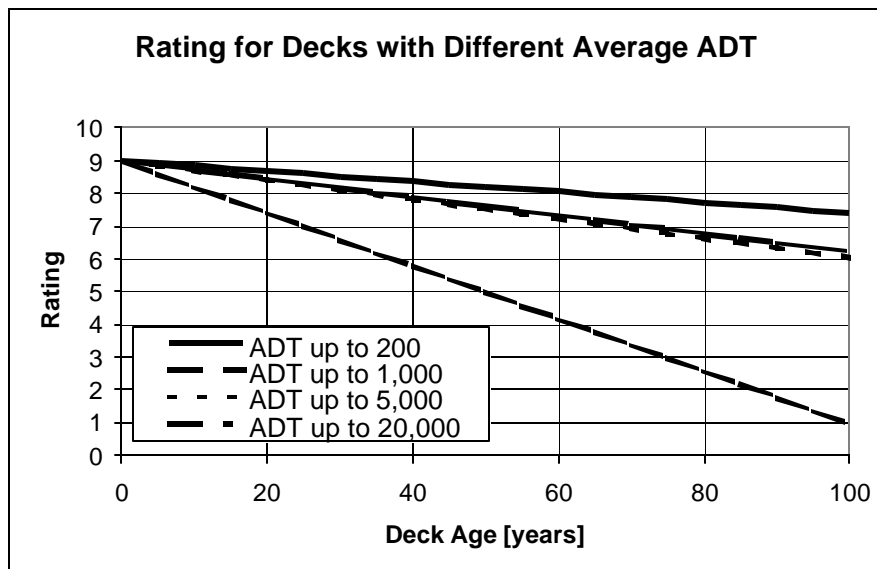


Figure 4-5. Linear regression lines for deck rating versus years of service.

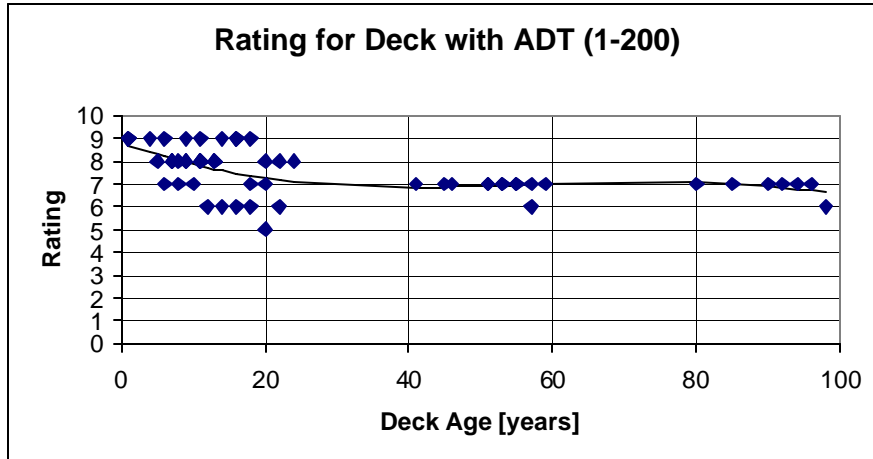


Figure 4-6. Nonlinear Regression curve for deck rating versus years of service (ADT 1-200).

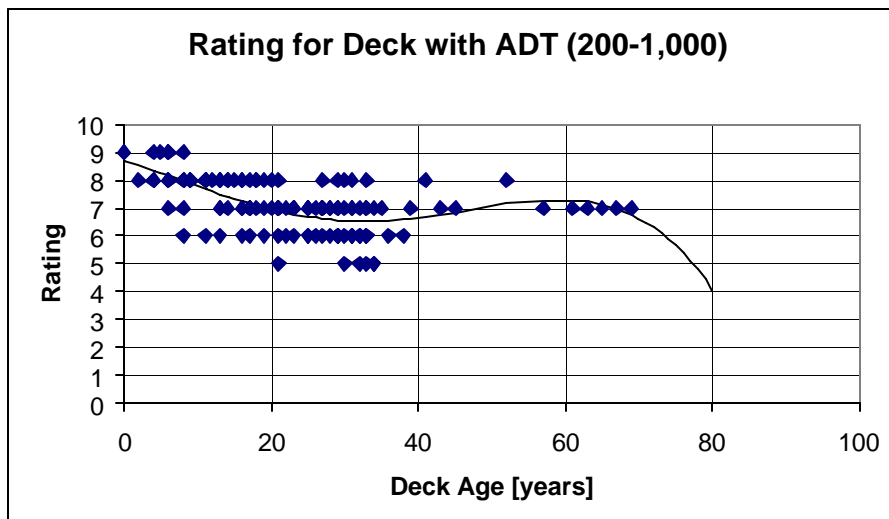


Figure 4-7. Nonlinear Regression curve for deck rating versus years of service (ADT 200-1,000).

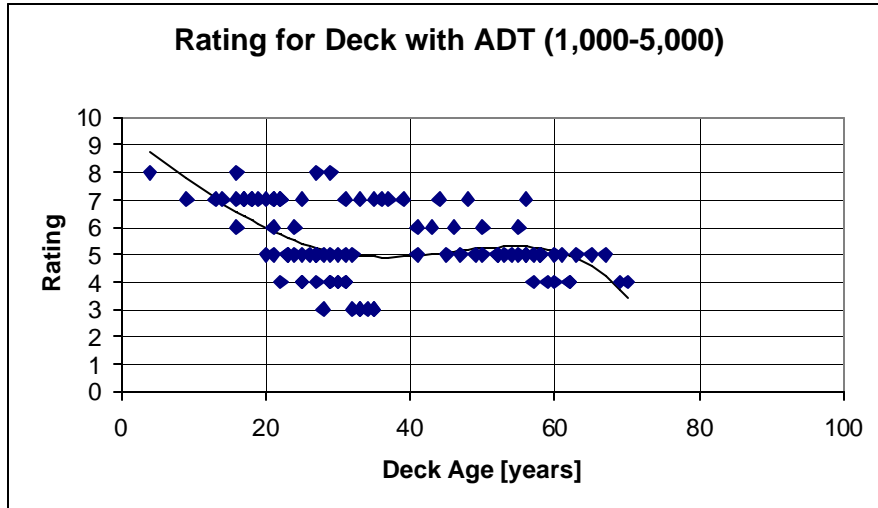


Figure 4-8. Nonlinear Regression curve for deck rating versus years of service (ADT 1,000-5,000).

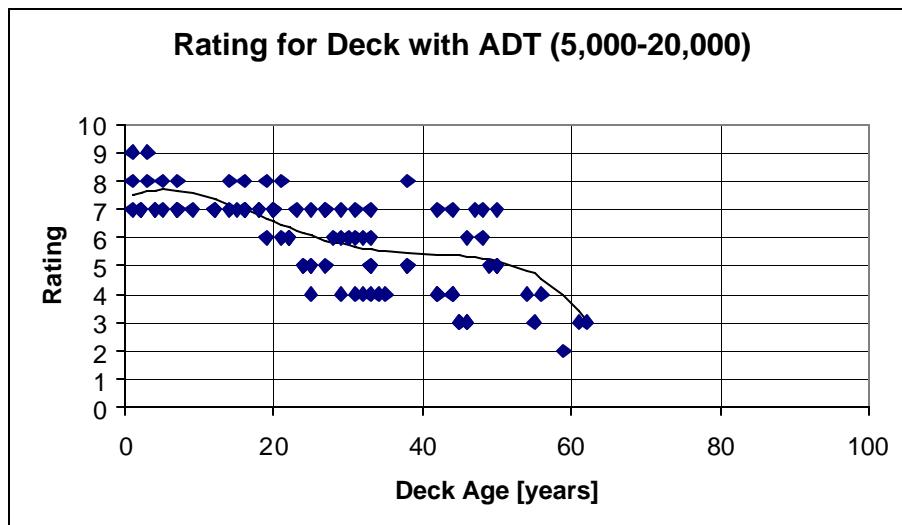


Figure 4-9. Nonlinear Regression curve for deck rating versus years of service (ADT 5,000-20,000).

## 5. EVALUATION PROCEDURES

In Michigan, a routine inspection of bridge decks is performed on a biannual basis.

Based on the FHWA's Bridge Inspector's Training Manual, to evaluate the condition and proper functioning of the deck, both the top and the bottom surfaces of the concrete deck should be inspected for cracking, scaling, spalling, corroding reinforcement, chloride contamination, delamination, and the depth failures such as potholes, crushed concrete and deep cracks. The main locations of possible damage in concrete decks include:

- areas exposed to traffic
- areas exposed to drainage
- bearing and shear areas, close to the supports
- top of the slab over the supports
- bottom of the slab between the supports
- top and the bottom of the slab in negative moment regions
- stay-in-place forms
- expansion joints
- acute corners of skewed bridge decks.

The inspection of the concrete decks primarily includes watching for visual defects, but hammers and chain drags can be also used to detect and quantify areas of delamination. In addition, core samples can be taken from the deck to determine the strength and chloride contamination in the laboratory. Electronic equipment can be used for checking rebar corrosion and delamination as well. Concrete decks which have a layer of asphalt as the wearing surface are more difficult to inspect and evaluate.

### 5.1 NBI (National Bridge Inventory)

Michigan's Structure Inventory and Appraisal Coding Guide has two inventory items for bridge decks. The first is item #58, which describes the overall condition rating of the deck. The condition rating used for this item is the NBIS General Condition ratings for bridge superstructures as shown in Table 5-1.

Table 5-1. Rating for bridge superstructure.

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION – no problems noted.
7	GOOD CONDITION – some minor problems.
6	SATISFACTORY CONDITION – structural elements show some minor deterioration.
5	FAIR CONDITION – all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION – advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION – loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION – advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored closing the bridge may be necessary until corrective action is taken.
1	“IMMINENT” FAILURE CONDITION – major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION – out of service – beyond corrective action.



The second is inventory item #58A, which describes the condition of the deck surface. The rating descriptions for this item are unique to Michigan as shown in Table 5-2.

Table 5-2. Rating for the deck wearing surface.

Code	Description
N	Not applicable
9	No noticable or noteworthy deficiencies, which affect the condition of the deck.
8	Minor (0.8 mm or 1/32") transverse crack with no spalling, scaling or delamination.
7	Sealable deck cracks (<1.6 mm or 1/16" wide), light scaling, (<6.4 mm deep). This area includes repaired areas and/or areas in need of corrective action.
6	Excessive number of open cracks (1660 mm or 5 ft intervals or less) over the entire deck. Medium scaling (6.4 mm to 13 mm or ¼" to ½" in depth) and/or 2% or less of the deck surface area is spalled or delaminated. This area includes repaired areas and/or areas in need of corrective action. Deck spalling may be limited to deck drains. Partial failures (delamination, pop-ups to top mat) but no full depth failures.
5	Excessive cracking with 2% to 10% of deck area spalled or delaminated. Heavy scaling (13 mm to 26 mm or ½" to 1" in depth). This area includes repaired areas and/or areas in need of corrective action. Deck deterioration is limited to cracks and deck drains.
4	10 – 25% of deck area is spalled or delaminated. This area includes repaired areas and/or areas in need of corrective action.
3	More than 25% of the deck area is spalled. This area includes repaired areas and/or areas in need of corrective action.
2	Emergency deck repairs required by the crews.
1	Bridge closed.

The condition of joints, expansion devices, curbs, sidewalks, parapets, fascias, bridge rail and scuppers shell are not considered in the overall deck evaluation, but their condition are typically noted during inspection.

## 5.2 PONTIS

The FHWA-Caltrans-AASHTO TWG developed the comprehensive BMS software called Pontis. Pontis helps bridge managers to effectively allocate limited funds for maintenance repair and rehabilitation of the bridges. Pontis is an agency wide network optimization system to address the improvement and maintenance needs of all bridges. The program has its own terminology which is unified, so all actions required on a bridge side have the same meaning. The Pontis database collects all data from the inventory and condition updates and is the authoritative source of the statistical data. Assignment of condition states to a bridge element is the Pontis method of rating an element during a field inspection. Five condition state designations are available; they are based on the most common forms of deterioration for particular element and the anticipated activity requirement. In Pontis, the condition description of a bridge element is a statistical profile rather than a precise measurement. The Pontis BMS is not designed to accommodate a particular type or style of inspection and because of it, a field inspection for Pontis input only is not specific enough to identify exact structural problems and not satisfy the criteria for a Safety Inspection. However, the basic Pontis BMS inspection procedures are not different from NBIS Safety Inspection only the documentation procedure is different.

The main feature of Pontis is its optimization capability. Optimization Models, as a part of Pontis program are prepared to find the long-term policy, for each element in each environment, to minimize the long-term maintenance funding requirements while keeping the element out of risk of failure due to deterioration. Pontis provides agencies the information they need to decide which short-term actions are most cost-effective for the long-term policy.

*Pontis Bridge Inspection Manual (PBIM)* is a document prepared to help in evaluation of bridge decks. It provides Deck/Slab Elements table, where each deck or slab element is specified and has a number. To quantify each element in a given condition state, PBIM describes all concrete decks and slabs structure elements, and five condition states according to the combined area of distress. Smart flags like Deck Cracking (on the top of

the deck) and Soffit Cracking (on the bottom of the deck) provide a description when these particular smart flags can be addressed. Deck Cracking smart flag has four condition states and Soffit Cracking smart flag has five condition states. Such classification helps to recognize the condition of the bridge decks in a more uniform way.

## **6. CONCLUSIONS AND SUGGESTED ACTIONS BASED ON DECK CONDITION STATE**

### **6.1 Conclusions**

In this guideline, the cause and effect of deterioration of bridge decks are discussed, and the most often observed types of deterioration are shown. It is seen that there are many parameters which influence the deterioration of bridge decks. Most often it is not possible to single out any one parameter that is the primary cause of a deteriorating bridge deck. It is also seen that the rate that bridge decks deteriorate is dependent on the ADT, with bridges having heavier truck traffic deteriorating at a greater rate. For a typical bridge deck, the deck's condition rating level drops quickly at first (from a new condition). This is attributed to the development of shrinkage cracking in the deck soon after it's construction. A typical decks condition rating, then tends to hold steady in the 5 to 7 range. With ongoing maintenance activities, deck ratings can even increase with time. Only with a lack of maintenance activity will a deck's condition rating decrease into poor or serious range.

### **6.2 General Recommendations**

MDOT has developed a *Bridge Deck Repair Matrix* (see Table 6-1) to help guide bridge engineers when making decisions on how to maintain and/or improve bridge decks. The matrix uses a bridge deck's NBI condition state, both deck top surface and underside surface, to suggest maintenance or rehabilitation actions to be taken. It can be seen from the matrix that there is an emphasize to maintain bridge decks when their condition state ratings are still in good condition. It is believed that these actions will increase the life of the decks and ultimately provide cost savings.

Table 6-1. Bridge Deck Repair Matrix

CONDITION STATE		Suggested Actions (3)	ANTICIPATED RESULT TO NBI		Next Anticipated Evaluation
Deck Surface Deficiencies (1) NBI #58a	Deck Underside Deficiencies (2) NBI #58		Item #58a Deck Surface	Item #58 Underside of Deck	
N/A	N/A	CSM Activies	No Change (5)	No Change (5)	1 to 8 years
2% to 5% (4) NBI = 5&6	<5%, NBI > 5	Deck patch/Seal Cracks/Polymer Ovly	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 pt	No Change	25 to 30 years
	5% to 30%, NBI = 3, 4 or 5	Shallow Concrete Overlay	Up by 2 pt	No Change	10 to 15 years
	> 30% NBI = 2 or 3	Bituminous Cap	Up by 2 pt	No Change	3 to 5 years
> 30% NBI = 3 & 4	< 5%, NBI > 5	Deep Concrete Overlay	No Change	No Change	20 to 25 years
	5% to 30%, NBI = 3, 4 or 5	Shallow Concrete Overlay	Up to 2 pt	No Change	10 years
		Bituminous Cap	Up to 2 pt	No Change	3 to 4 years
	> 30%, NBI = 2 or 3	Replace Deck	NBI now 9	NBI now 9	40 + years
		Bituminous Cap	No Change	No Change	1 to 3 years

## **7. REFERENCES**

ACI Manual of Concrete Practice, Part 1, Ch.3, ACI 201.1R-98, “Guide of Making a Condition Survey of Concrete in Service

“Development of a Procedure for Efficient Evaluation of Bridge Decks”, Report No 98-1303, submitted to the Michigan Department of Transportation

FHWA’s Bridge Inspectors Training Manual/90

Michigan’s Bridge Repair Matrix

Michigan’s Structural Inventory Database

NHI course 13055, “Safety Inspection of In-Service Bridges”

PONTIS Bridge Inspection Manual