New York State Department of Transportation Bridge Inspection and Rehabilitation Design Program

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The New York State Department of Transportation bridge inspection and rehabilitation design program was developed to provide a formalized procedure to be used in making effective rehabilitate/replace decisions for a variety of bridges. Use of the procedure also provides most of the information required for preparation of contract documents if the rehabilitation option is selected. This paper provides detailed information about the steps included in the procedure, a discussion of the criteria used in making the rehabilitate/replace decision, and a case study that shows the application of the procedure to a specific bridge. The Department has successfully used the procedure for 150 bridges, and 100 more are currently included in the program, which requires its use. The use of the procedure has resulted in sound rehabilitate/replace decisions and contract documents for cost-effective bridge restorations.

The purpose of the New York State Department of Transportation (NYSDOT) bridge inspection and rehabilitation design program is to provide the information required to make the rehabilitate/replace decision, and, if rehabilitation is selected, to provide much of the information required for the preparation of contract documents for the rehabilitation work. Rehabilitation, as differentiated from routine maintenance, safety upgrading, or bridge deck repairs, usually involves complete deck replacement and superstructure and substructure repair or strengthening. Rehabilitation has as its objective the restoration of a bridge, to the greatest extent possible, to a like-new condition and, if necessary, the improvement of bridge geometrics and load-carrying ability.

For many bridges, the decision that rehabilitation is the only viable alternative can be made at the time of project initiation; replacement is not considered. In these cases, the decision is not related to the condition of the bridge, but instead is dictated by external constraints, such as the need to maintain traffic on the bridge during construction; the high cost of using an alternate location for the bridge in terms of right-of-way costs, displacement of people and businesses, and the related lengthy procedures that involve environmental analyses and public hearings; and, perhaps most important, the much higher cost of replacement of the bridge when compared with rehabilitation.

The decision to rehabilitate rather than replace is most easily made when the bridge is a major structure in an urban area. In this situation, the choice of the rehabilitation option is invariably dictated by the external constraints mentioned above. The bridge program contains many projects in this category, primarily medium to large bridges and viaducts in New York City and other urban areas.

At the other end of the scale, a small bridge in a rural area is invariably replaced rather than rehabilitated. The replacement option is normally selected because the condition of the bridge is usually bad, which makes rehabilitation very costly; the bridge is too narrow to meet reasonable standards; it is a type (through truss or girder, concrete beam and slab) that cannot be readily widened; the substructures are of questionable condition and load-carrying ability; and the replacement can be done without problems caused by the external constraints cited earlier. The bridge program also contains many projects in this category, primarily small to medium-sized bridges in rural and suburban areas in upstate New York.

Between these two extremes is a group of bridges, usually not large in number in a total bridge program, for which the decision cannot be made without further investigation. The bridge inspection and rehabilitation design program is specifically used in helping to make this determination and for providing much of the information required for preparing plans, specifications, and estimates for the rehabilitation of the bridge when that is the option selected.

BRIDGE INSPECTION AND REHABILITATION DESIGN PROGRAM

The bridge inspection and rehabilitation design program contains seven steps, taken in the following order:

1. Project identification and initiation,
2. Bridge inspection,
3. Acquisition of supplemental data,
4. Load rating of the bridge,
5. Bridge rehabilitation project report and preliminary plan preparation,
6. Rehabilitate/replace decision, and
7. Contract document preparation if rehabilitation is the decision, or recycle as a replacement project if not.

The first five steps are common to projects for which the rehabilitate/replace decision must be made and those for which external constraints dictate the decision. If the decision to rehabilitate is made earlier because of external constraints, step 6 (rehabilitate/replace decision) is skipped and step 7 (contract document preparation) is started immediately. If the decision was not made earlier, step 6 is included. Based on the decision in step 6, step 7 will consist of the preparation of rehabilitation plans and estimates based on agreements reached on the recommended scope of the work as defined by the bridge rehabilitation project report and preliminary plan or the development of the project as a bridge replacement project. Details of each step are given in the following sections.

Project Identification and Initiation

The selection of a bridge for the program is made by the regional office of the Department in which the bridge is located based on detailed knowledge of the bridge, including age, condition, and the bridge priorities within the region.

The selection process is facilitated by the information generated from the Department's bridge inspection program. This program consists of a statewide, standardized, visual inspection that results in the assignment of numerical ratings to the principal components of each bridge inspected. The inspector also provides an overall bridge condition rating and recommendation for each bridge. The program requires the inspection of each bridge in New York State each two years and was developed to respond to the requirements of the National Bridge Inspection Program. The ratings of each bridge component are weighted and used to produce a listing of structurally deficient bridges. This listing is issued annually and shows bridges in priority order. It is produced in the main office of the Department by the Bridge Inventory and Inspection Unit of the Structures Division. In addition, the regional offices are provided with copies of the Federal Highway Administration (FHWA) selection list for use as a resource in this activity. The federal selection list also uses state bridge condition information, but combines it with traffic and other information. The result is a listing that varies somewhat from the state listing but that is also a valuable tool in the process of program development.

Regional offices submit initiation requests for bridge rehabilitation and bridge replacement projects based on available funds, the priorities shown on the structurally deficient bridge lists, and knowledge of each bridge and how it relates to the total bridge needs of the region. After review and acceptance in the main office of the Department, projects are placed in the Department's program and a designer, either from within the Department or a consulting engineer directed by the Department, is designated to perform the remaining activities.

Bridge Inspection

The bridge inspection used in the bridge inspection and rehabilitation design program is defined by NYSDOT as a high-quality, in-depth engineering study. It is an inspection tailored to identify all problems of a specific bridge. The Department requires that the inspection, if done by a consulting engineering firm, be personally supervised by a professional engineer registered in New York State with at least three years experience in bridge inspection or related bridge work. Inspections done by state staff are also supervised by experienced professional engineers.

In order to ensure that there is uniformity in the quality and methods used for the inspection, the Department has written a specification (1) for this purpose. This specification was developed from material in the American Association of State Highway and Transportation Officials (AASHTO) Manual for Maintenance Inspection of Bridges (2), the FHWA Bridge Inspector Training Manual (3), and by gathering information and suggestions from the Department's main and regional office personnel who have had experience in bridge inspection.

Two points should be emphasized with regard to the specification for in-depth bridge inspection:

1. Besides setting the minimum inspection requirements, the specification contains the following instructions for the engineer conducting the inspection: "Due to the varying nature of original designs, construction techniques, and materials, it is impossible to state every observation, measurement, and test that should be made to properly evaluate every bridge. The engineer shall view each bridge separately and make observations, perform tests, make measurements, etc., beyond the minimum criteria established in this specification as may be necessary to become reasonably certain as to the condition of the bridge and its ability to function properly."
2. The specification is periodically revised based on the Department's assessment of the results obtained to that time. This usually involves expanding or refining a particular inspection requirement.

For example, the original specification contained no provision for determining if the superstructure expansion joints were actually functioning or how much expansion was occurring at a particular location. After encountering problems in determining the sizes of joint-seal assemblies needed on some steel-bent structures, it was decided to add a requirement for measuring the existing joint openings twice, with at least 40° differential in temperature between the times of the measurements.

The in-depth inspection is literally a hands-on inspection. All deteriorated and suspect areas of the bridge are closely examined and their condition recorded. Concrete is sounded and cored for laboratory analysis. Steel losses are measured. The structure is surveyed for settlement and alignment and clearance deficiencies. In addition, the approaches of the bridge are inspected. Occasionally, these inspections reveal deterioration so extensive that the bridge cannot be rehabilitated. In these cases, the in-depth inspection is terminated and the project is reprogrammed as a bridge replacement. When this is done, one or more of the following actions are taken, if required, to ensure the safety of the bridge user until the replacement bridge is available for use. The bridge may receive emergency repairs, may be load or speed posted, have existing postings lowered, or, if conditions warrant, it may be closed.

Supplemental Data

In addition to the inspection data, additional information is required to provide a total overview of the bridge and its relation to the highway it serves. This information includes

1. Highway design speed obtained from classification or local speed postings;
2. Traffic volumes obtained from traffic counts routinely taken by the Department or highway owner if other than the Department; if no traffic counts exist, they are taken as a part of the inspection activity;
3. Lane requirements obtained from traffic volumes and the highway classification;
4. Accident data on and in the vicinity of the bridge obtained from police records or accident data gathered by the Department as a part of a program to identify locations with high numbers of accidents; and
5. Substandard features obtained from a comparison of existing geometrics with AASHTO standards.

Load Rating

By using the actual meaurements obtained from the hands-on inspection, a load-rating analysis of the existing bridge is made in accordance with the current AASHTO manual (2). This analysis is done to the same level of accuracy and detail as is used when a bridge is designed. Once computed, this rating goes into the bridge inventory files of the Department and is used to report inventory and operating ratings to FHWA. These ratings are also used to make determinations on overload permit requests or to alert the maintaining agency of the need for emergency repairs or posting of the bridge for a reduced load.

Bridge Rehabilitation Project Report and Preliminary Plan

All of the information gathered in steps 1 through 4 is combined into the bridge rehabilitation project report. This report contains complete recommendations regarding the details of the work to be done on the bridge and justifications for retaining any substandard conditions on the rehabilitated bridge or its approaches. A preliminary plan accompanies the report, which shows the existing plan, profile, and typical section; the proposed plan, profile, and typical section; and the typical repair details. Cost estimates for the proposed rehabilitation work are also included.

After agreement is reached between the designer and the approving agency as to the most feasible approach to the restoration of a particular bridge, the preliminary plan is modified, if necessary, to reflect this approach. This plan becomes the approved method of rehabilitation if the rehabilitation option is subsequently selected.

Rehabilitate/Replace Decision

If external constraints have not already dictated that the bridge must be rehabilitated, the decision to rehabilitate or replace is made at this time. The major influence on this decision is cost. A general criterion is that a rehabilitation project with a cost of more than half the cost of a new bridge should not be built; instead, the bridge should be replaced. This criterion is not based on any refined statistical studies but rather is based on results from experience over the past 15 years in New York State. Two factors have been identified that support this subjective criterion:

1. The amount of work to be done when rehabilitating a bridge inevitably grows during construction. Even with the best in-depth inspection and evaluation, some items that require repair may be overlooked, some items cannot be found until the construction work uncovers them, deterioration continues during the period between the inspection and the start of construction work, and the rate of deterioration is difficult to estimate and account for in the plans and estimates. Further, those responsible for the construction of bridge rehabilitation projects must constantly walk the line between doing too little work and not achieving the design life of the project, and doing so much that the cost of the project escalates dramatically during construction. This problem can be reduced (but not eliminated) by spending more on the in-depth inspection. However, this is not popular with administrators who are accountable for what appears to be disproportionately high costs for preliminary engineering when this is done. Another way of controlling the problem is to raise preliminary estimates to compensate for overruns, but this is speculative and would be objectionable to some engineers.

2. The bridge, after rehabilitation, is unlikely to perform as long or as economically as a new bridge built at the same time. The rehabilitated bridge will be a hybrid of new and old design concepts, detailing concepts, and material types and as such cannot be expected to function as well as a new bridge that reflects the current state of the art. Also, the inevitable dilemma of when to stop removing deteriorated concrete or steel during construction results in compromises that may affect the useful life of the rehabilitated bridge.

Other criteria applied when making the rehabilitate/replace decision include the ability of the bridge to be readily rehabilitated. Some bridge types are relatively easy to rehabilitate and widen, such as stringer bridges, while others, such as through trusses and through girders, are not. Concrete bridges are difficult to rehabilitate unless the concrete is very sound; low strength or partly deteriorated concrete is not easily restored.

The vertical and horizontal geometry and load-carrying ability of the bridge must also be considered. A bridge with poor geometrics and a bad accident record should not be retained but instead should be replaced. One that must have a load restriction even after rehabilitation should be replaced unless the load restriction will cause no economic disadvantage to the area served by the bridge.

These are general criteria, and exceptions must be made on occasion. The decision is not easy in many cases and is only made after much investigation and evaluation. Ultimately, it is often based on subjective judgments.

Finally, many of these criteria can be applied before detailed inspection. Geometry, strengthening, and ease of rehabilitation should be considered at step 1, and the final decision made at that time if possible. This results in a project that is completed more quickly with the resultant saving of sizable amounts of engineering time and cost.

Contract Document Preparation

Following the rehabilitate/replace decision, plans are prepared for either a rehabilitation project or a replacement project. If a rehabilitation project, the inspection already performed is the basis of the preparation of plans, specification, and estimates, with follow-up inspections during plan preparation as required to get detailed information. If a new bridge is to be built, the project is recycled in conformance with the owning agency's procedures for a bridge replacement project. Because of the amount of work required for the inspection and other supporting activities, it is clear that much engineering time is lost in those cases where the replacement option is selected. For this reason it is very important to stop the process at any time it becomes clear that replacement becomes the favored option. It should also be understood that the procedure should not be used unless funds are available to immediately prepare plans and specifications for remedial work and let contracts promptly because of the cost and the limited time that the in-depth inspection has value.

CASE STUDY

The following is a case study that provides an example of how this procedure works. The bridge discussed is the Third Avenue (Owl's Head) Viaduct located in the Borough of Brooklyn in New York City. Figure 1 shows the general location of the project, which is adjacent to Owl's Head Park at the point where the Shore Parkway transitions into the Queens Expressway. Figure 2 shows the location in greater detail.

The viaduct consists of 39 spans with a total length of 3816 ft. Each span consists of a reinforced-concrete deck slab supported on structural steel floor framing, as shown in Figure 3. The steel floor framing, in turn, is supported by structural steel bents that consist of steel columns, cap beams, and floor beams with cantilevered steel brackets, as shown in Figure 4.

In general, the viaduct carries four lanes of traffic on two 24-ft roadways (one in each direction) separated by a 4-ft-wide raised-concrete median and flanked by 18-in safety walks at both fascias for a total width of 55 ft between railings, as shown in Figure 5.

An entrance ramp from Third Avenue and 65th Street is connected to the viaduct and the deck widens to accommodate an acceleration lane at this point.

The total concrete deck area of the Third Avenue Viaduct is 163 300 ft^2. The viaduct carries 59 000 automobiles/day. No trucks are allowed.

The viaduct passes over seven city streets and three parkway interchange ramps (one of which extends lengthwise under 10 spans). The remaining areas under the viaduct are occupied by a military and naval maintenance shop (four spans), a playground (five spans), and an apartment house parking lot (two spans).

The viaduct was constructed during two different periods some 20 years apart. The 28 southerly spans are what remain of a 34-span structure built from plans dated December 1940. At the north end, 6 spans of the original structure were subsequently removed and replaced by the current 11 northerly spans together with the connection between the Gowanus Expressway and the Verrazano-Narrows Bridge.

The older section of the viaduct was designed for H20 loading, based on the 1935 American Association of State Highway Officials (AASHO) specifications. The newer section was designed for H20-S16 loading based on 1957 AASHO specifications.

This structure was proposed for rehabilitation by the regional office in January 1977 as one of nine structures on the Belt Parkway in Kings and Queens Counties that were in need of major rehabilitation if the parkway was to remain a usable facility. The overall structure rating, based on visual inspection, was listed as falling between minor deterioration and serious deterioration. The structure was placed on the Department's program and a consulting engineering firm was retained to perform the activities discussed earlier, beginning with the in-depth bridge inspection and finishing with the preparation of contract documents.

The actual inspection of the viaduct commenced in June 1977 and was finished in April 1978. The inspection was conducted by two four-person inspection crews, a survey crew, and a concrete coring crew, and included the following:

1. The vertical and horizontal components of the viaduct were completely surveyed, including a check for column plumbness and settlement.
2. The wearing surface was mapped for cracking and the underside of the deck was sounded by hammer and mapped. Eighty-two cores were taken from the deck.
3. The 1600 individual steel members were examined, and approximately 2000 steel-loss measurements were taken.
4. The railing, drainage, and joint systems were inspected and the deficiencies recorded.

A wide variety of equipment was used to provide access to the viaduct, as shown in Figure 6. Approximately 2000 color photographs were taken during the course of the inspection for documentation of conditions. This figure was made from some of the photographs. Office work and acquisition of supplemental data progressed at the same time the field activities were under way. The bridge rehabilitation project report and preliminary plans were distributed for review in September 1978.

The basic findings and recommendations were as follows:

1. The deck had deteriorated beyond the point of being repairable and complete replacement was recommended. Figure 7 show typical deck conditions.
2. New joint systems were required because the existing systems were not functioning, as shown in Figure 8.
3. New drainage systems were needed because the existing systems were beyond repair, as shown in Figure 9.
4. A new railing system was included because the existing system was deficient, as shown in Figure 10.

Figure 1. Overview of project area.

Figure 2. Detail of project area.

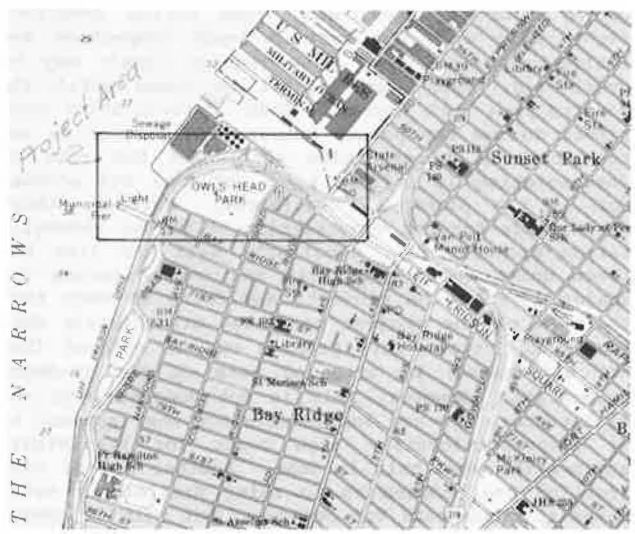


Figure 3. Support for reinforced-concrete deck slabs.

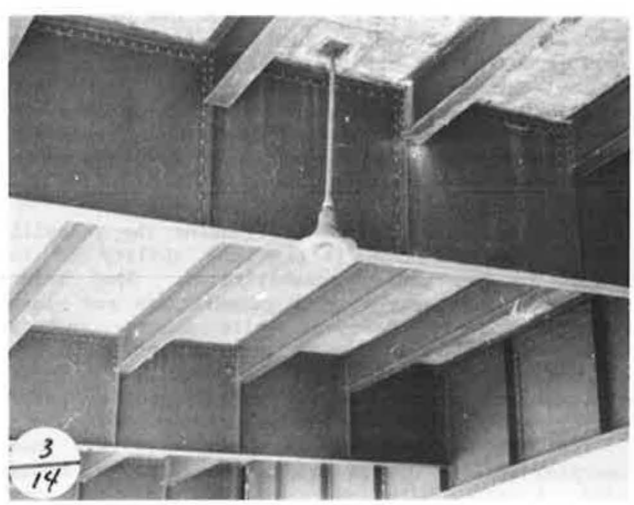


Figure 4. Structural steel bents.

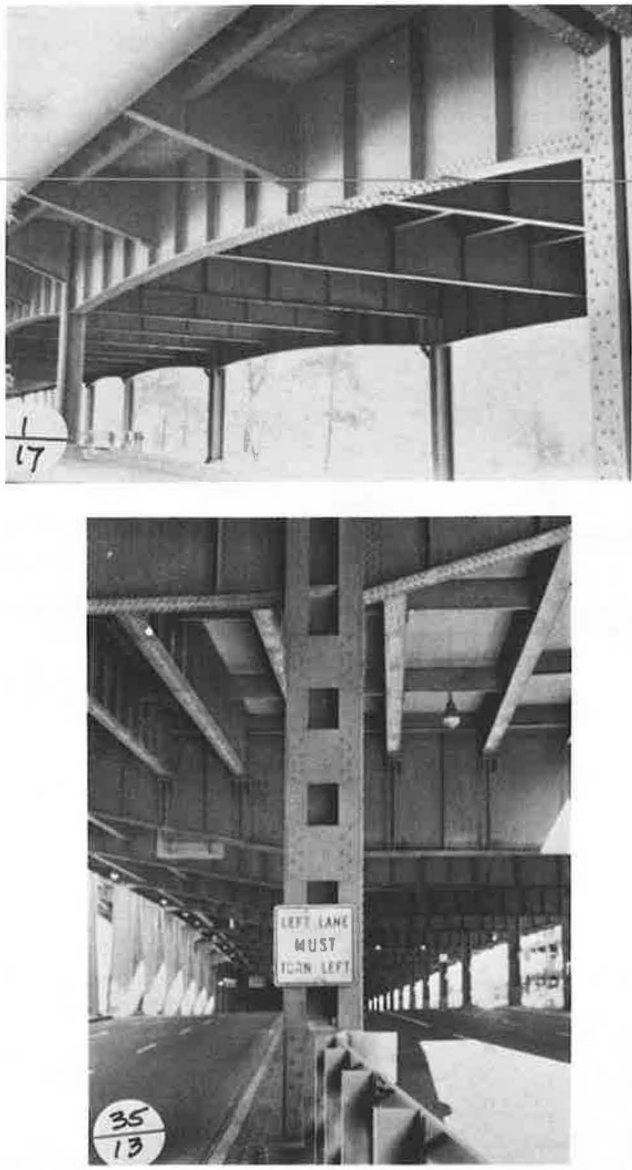
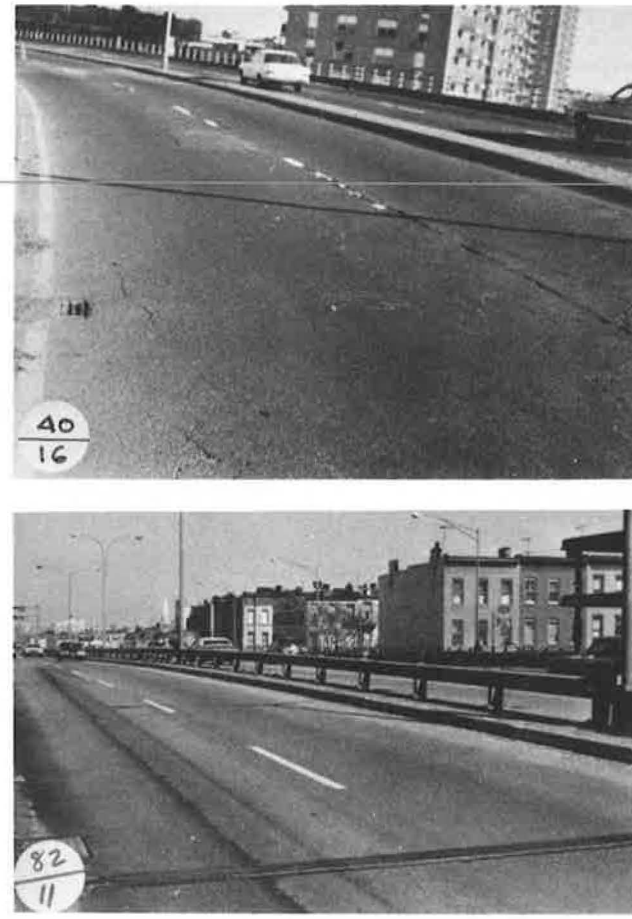


Figure 5. View of roadway.



5. Some 30 percent of the 1600 steel members were recommended for some kind of repair or replacement, primarily because of deterioration brought about by leaking deck joints or faulty deck drainage, as shown in Figure 11.
6. Substructure steel and concrete required repair or replacement, as shown in Figures 12 and 13.

The load rating of the bridge, even with the steel losses, was judged sufficiently high to carry passenger car traffic until rehabilitation was completed. One temporary repair was recommended and made. The major substandard feature on the viaduct was the lack of shoulders. It was recommended that the viaduct not be widened because of cost, right-of-way requirements, and its relation with adjoining and connecting facilities.

The recommendations were accepted by the Department and the City of New York but, because of accident records found subsequently, it was decided to expand the scope of the project in order to allow the upgrading of the acceleration lane at the southern end of the project. This required further field and office investigation by the consulting engineer. Also, because of community concerns, the maintenance and protection of traffic plans had to be revised several times. In July 1979, the final concept of the project was approved and work began on the contract documents.

The contract documents were finished in April 1980, the contract was let in June 1980, and construction was completed in February 1982. The costs for the project are given in the table below:

Item	Cost ($000 000s)
Design engineering (inspection and contract documents)	1.15
Contractor's bid price	14.07
Orders on contract	1.22
Construction supervision (included inspection of top flanges after deck removal and checking of shop drawings)	1.70
Total	18.14

The orders on contract were required for extra top flange repairs that were not apparent until the deck was removed, additional street paving that was added to the contract after it was let, revisions to the maintenance of traffic requirements because of problems encountered during construction, and because of some errors in the original estimate.

The project was judged successful because the work was done with minimal additional cost during construction. Further, the $18 million cost of the project was about 50 percent of the $35 million replacement cost for the viaduct, thereby meeting the first criterion for assessing the rehabilitate/ replace decision. In the context of the other criteria, the bridge was easy to rehabilitate, it had no load restriction, and the only geometric deficiency remaining was the lack of shoulders. Operational characteristics were improved through modification of an acceleration lane.

Projects of this magnitude are normally designed by consulting engineers, since the number of personnel and types of equipment required for the in-depth inspection and plan preparation, if taken from departmental resources, would severely deplete those resources. Similar projects of smaller scale have been done by departmental staff. If departmental

Figure 6. Inspection equipment.

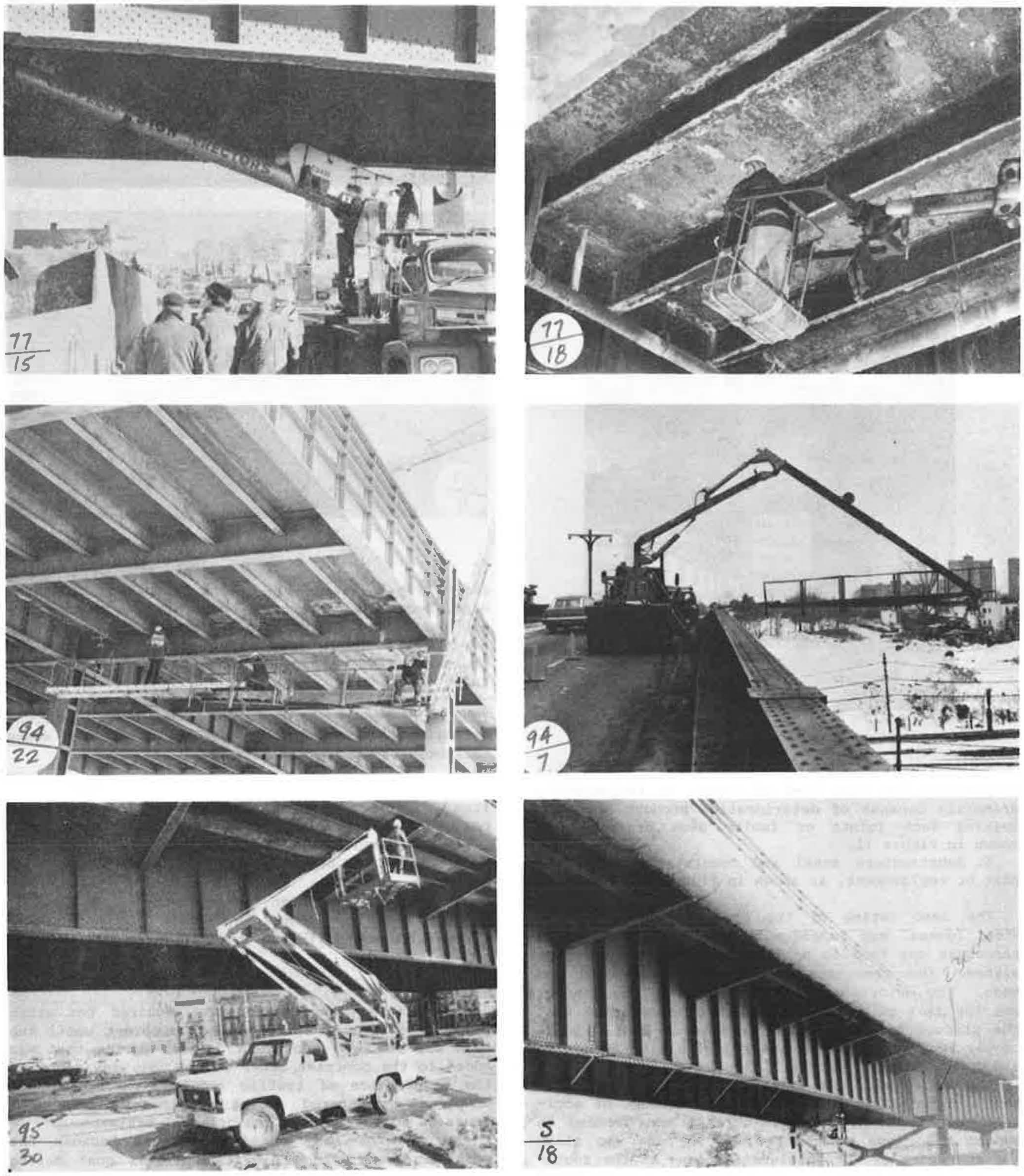


Figure 7. Deck deterioration.

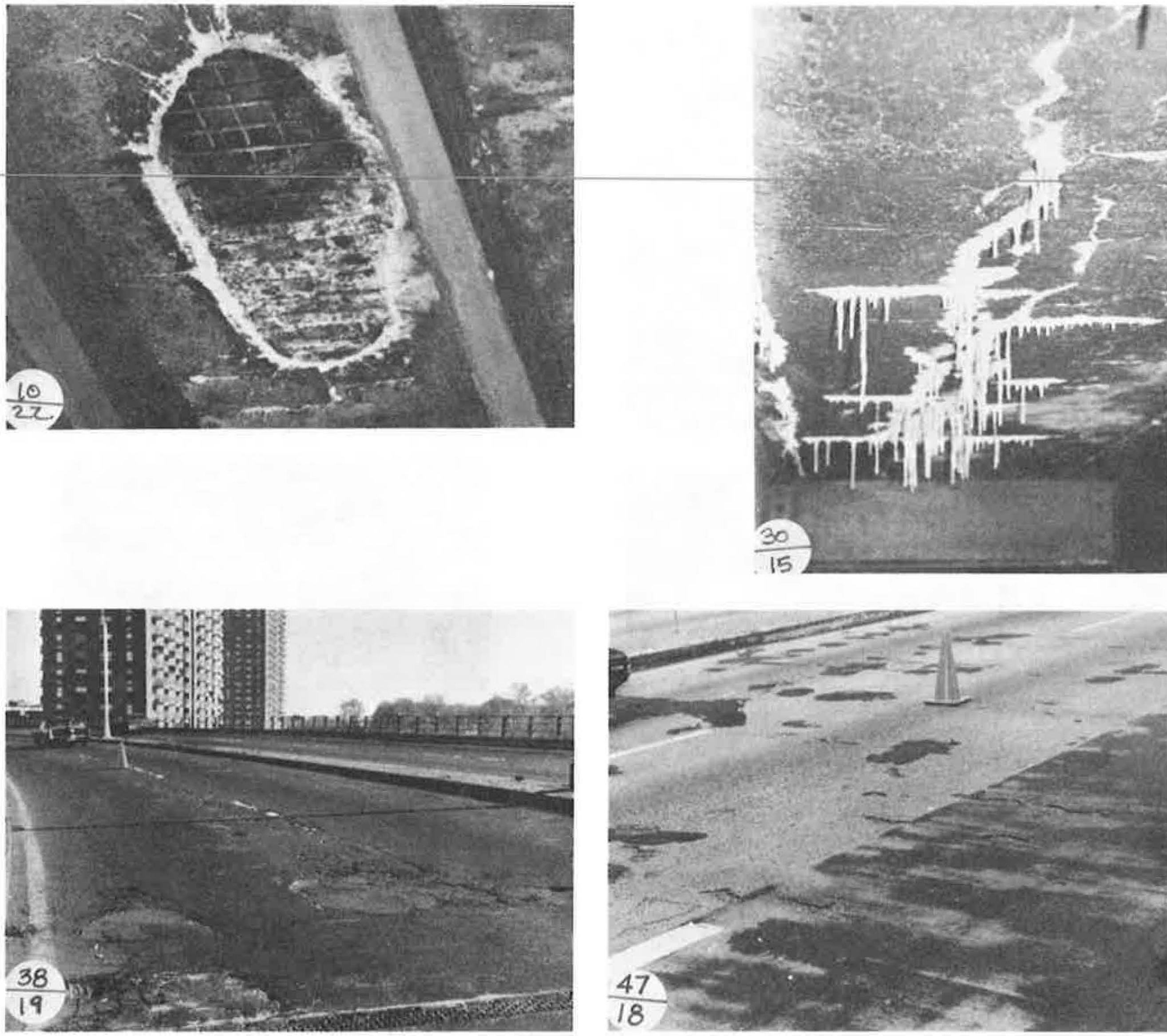


Figure 8. Deteriorated joint system.

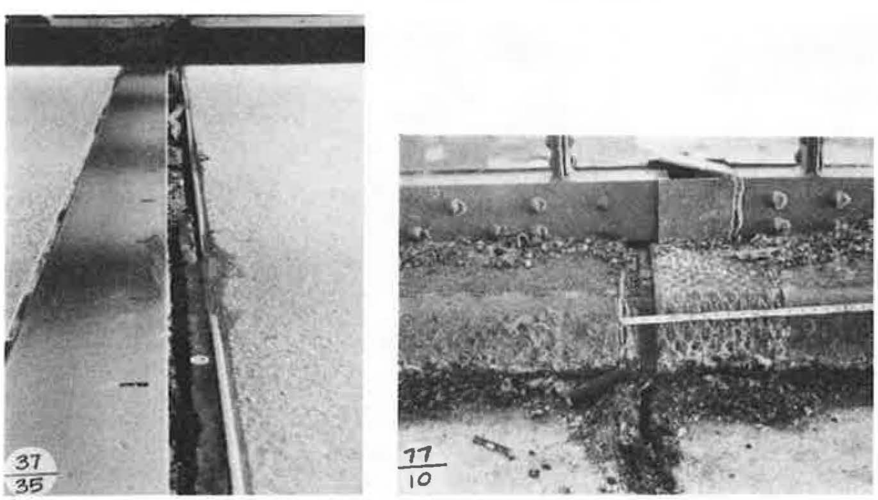


Figure 9. Deteriorated drainage system.

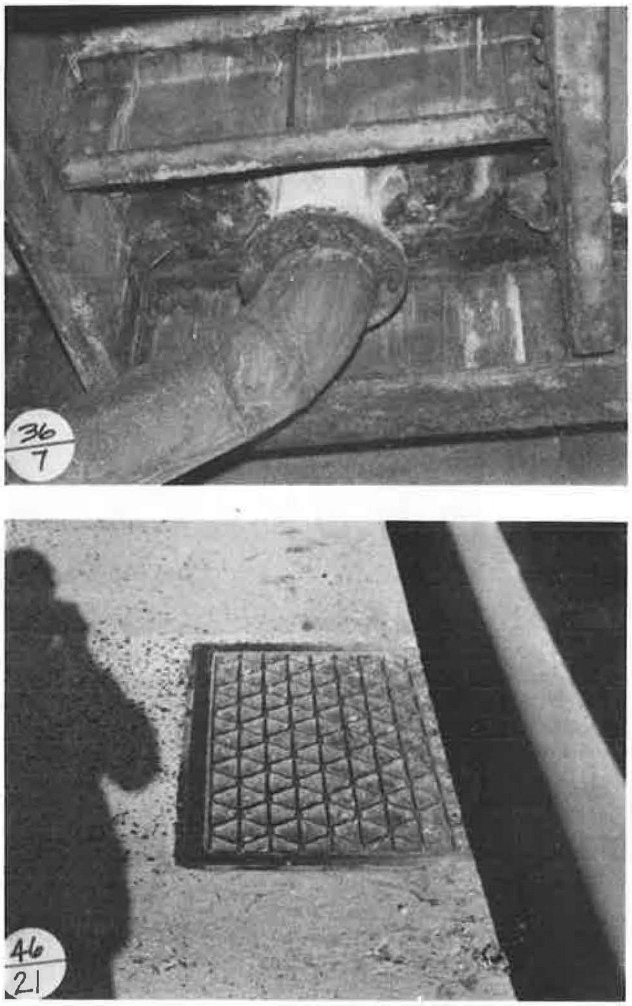


Figure 10. Deterorated railing system.

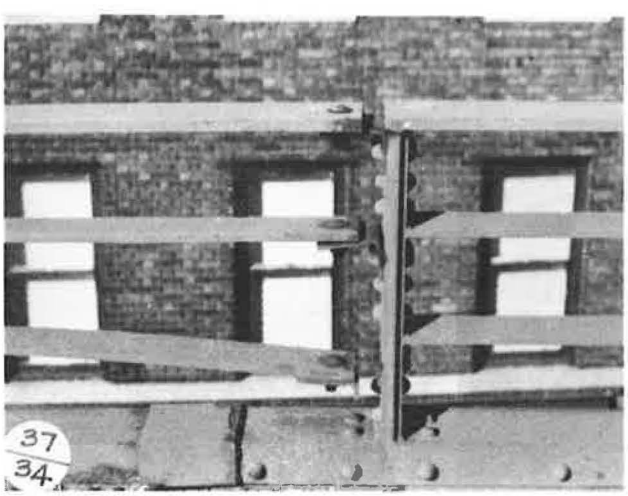


Figure 11. Deteriorated steel member.

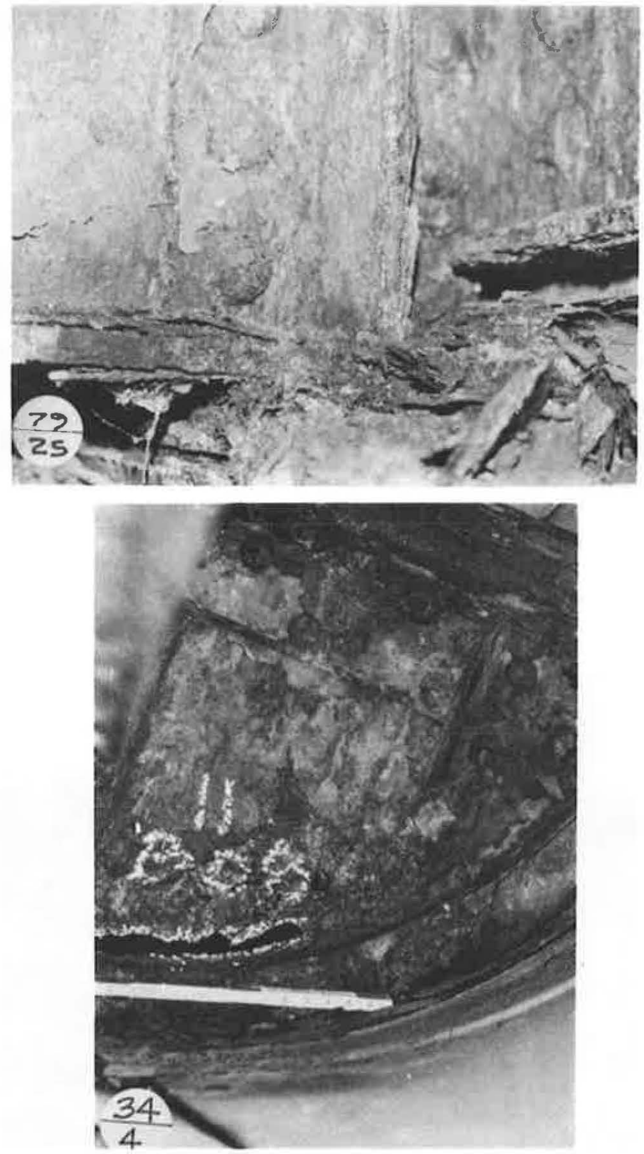


Figure 12. Deteriorated steel.

Figure 13. Deteriorated steel and concrete.

staff are used, they may be from the Structures Division in the main office or from the regional office in which the project is located. The preferred pattern is to use staff headquartered close to the bridge in order to minimize the travel time needed for the frequent trips required to the bridge. If consulting engineers do the work, they are managed by the Structures Division with strong support from the regional office in which the bridge is located. Those managing consulting engineers at the regional level do it as a part of a variety of bridge design and construction activities. In the Structures Division, a specific unit is responsible for consultant management, including consulting engineers who design new bridges as well as rehabilitation projects. Staff managing consultants are either professional engineers or work under the direct supervision of professional engineers. Each staff member is responsible for 15-20 projects.

CONCLUSION

In conclusion, the Department considers the bridge inspection and rehabilitation design program to be an effective way to assist with the rehabilitate/replace decision and to provide the material needed to produce reliable contract documents for construction.

Of the 150 New York State projects that have followed this procedure, only 8 bridges were reprogrammed from rehabiliation to replacement, which attests to care given the selection of bridges for the program and the prominent place of external constraints in dictating what will happen to the bridge. Some might argue that the small number of changes would indicate that the rehabilitate/replace decision point is unnecessary. It is the Department's view that the possibility of a change should always be a consideration in order to ensure that the best solution is developed for each project.

The number of deteriorated bridges in New York State and across the country make it obvious that total replacement of all these bridges is not possible. Instead, an inspection and rehabilitation design program, if properly managed, can be used to make cost-effective restorations of many of these bridges.

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Pennsylvania's Structure Inventory Record System: SIRS

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Pennsylvania's newly implemented computerized structure inventory record system, which incorporates data in excess of federal inventory and inspection requirements, is described. These data codify and describe the actual condition of more than 16 000 bridges on the state system and more than 5000 bridges on the local system. This paper also describes the system's management, identification codes, update requirements, and security. Also provided is a general understanding of the system and its error correction, updates, and enhancement. This system produces a series of reports for use in the verification of data and the technical content of the system. The data are converted internally from Pennsylvania data to Federal Highway Administration data to satisfy frequent reporting requirements.

This paper gives an overview of the recently implemented on-line structure inventory record system (SIRS) in Pennsylvania. The Bureau for Strategic Planning, Pennsylvania Department of Transportation (PennDOT), exercises a quality-control function over several planning information systems. This paper covers one of the information systems.

Because the Bureau of Highway Design is responsible to carry out the bridge inventory and inspection program, they are the primary users of SIRS. The primary data are gathered by the district bridge units, which are also users of the system. The Bridge Division in the central office in Harrisburg, Pennsylvania, monitors district activities that concern technical and bridge engineering data.

SIRS represents an on-line computerized bridge inventory system that provides direct data entry and retrieval. Information on bridges is collected, quantified, and entered into the on-line system through remote terminals within one day to two weeks after field collection of the raw data. Priority was given to enter bridges 20 ft and longer because such structures are defined by the Federal Highway Administration (FHWA) as bridges. This system was