DEVELOPMENT OF A SAFETY-INSPECTION METHODOLOGY FOR RIVER BRIDGES

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ABSTRACT

DEVELOPMENT OF A SAFETY-INSPECTION METHODOLOGY FOR RIVER BRIDGES

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River bridges get damaged or even collapse because of various reasons, such as development of adverse hydraulic conditions during severe floods, disastrous earthquakes, deficiencies in structural and geotechnical design, material deficiencies, or other unexpected external factors. Failure of service at vital lifelines, bridges, can lead to loss of several lives and properties, traffic disruption, and/or deficiencies in daily usage. Existing structures should be monitored periodically for decision-making and necessary protective works should be implemented to increase the safety. Types of items to be inspected would be categorized as structural, geotechnical, hydraulic, and status of materials. Requirement for periodic inspections and the ways of handling these activities are discussed within the framework of aforementioned aspects with special reference to the current situation of river bridges in Turkey and current practices in USA. An algorithm, composed of sets of checklists, is proposed. In such an algorithm, rank-based prioritization of events is identified. The evaluation and interpretation are displayed with the help of a few case studies, selected among several river bridges around Ankara.

Keywords: River Bridge, Safety, Inspection, Maintenance

ÖZ

AKARSU KÖPRÜLERİNDE EMNİYET TETKİKLERİ İÇİN BİR YÖNTEM GELİŞTİRME

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Akarsu köprüleri, taşkın sebepli oluşan olumsuz hidrolik koşullar, afetler, zeminsel ve yapısal problemler ve beklenmedik dış faktörler sebebi ile zarar görebilir ve hatta yıkılabilirler. Önemli ulaşım hatlarında olan köprülerde oluşan bozukluklar, birçok insan hayatının kaybına, trafikte aksamalara ve günlük hayattaki kullanımlarda eksikliklere neden olmaktadır. Mevcut yapılardaki güvenliği arttırmak için bu yapılar düzenli şekilde denetlenmeli ve olası problemler saptanıp, gerekli koruyucu önlemler alınmalıdır. Denetleme sırasında incelenecek öğeler yapısal, zeminsel, hidrolik ve malzeme açılarından olmak üzere gruplanmıştır. Periyodik denetlemenin gereklilikleri, bahsi geçen bu faktörler ele alınarak ve Türkiye'deki mevcut köprüler ve A.B.D'deki pratik örnekler kullanılarak incelenmiştir. Kontrol listesi grupları oluşturularak, bir algoritma önerilmiştir. Bu algoritmada, olayların dereceli öncelikleri belirlenmektedir. Değerlendirme ve yorumlama, Ankara çevresinden seçilmiş akarsu köprülerinin yardımı ile ortaya konmuştur.

Anahtar Kelimeler: Akarsu köprüsü, Güvenlik, Denetim, Bakım

To my mom and dad,

For their endless patience and support

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D_m : bridge or culvert distance from meander impact point

R : hydraulic radius

S : channel bed slope

α : high flow angle of approach to bridge or culvert

γ : specific weight of water

τ_c : critical shear stress at which bed material particles begin to move

τ_e : shear stress ratio

τ_o : average boundary shear stress

CHAPTER 1

INTRODUCTION

1.1 Statement of Problem

Bridges need periodic inspection and maintenance during their life time as they might have defects due to the developments of various adverse effects, some of which are induced by external impacts, e.g. floods, chemical spills, and earthquakes, whereas the other factors may result from the improper design, construction, and maintenance. Defect-resistant design with proper construction and early diagnosis may provide great advantages not only from viewpoints of safety and economy but also from social, environmental, and ethical aspects.

Bridge maintenance has started to be an important and common practice in the last half century in the world, after facing with great catastrophic bridge failures, concluded with life and economical losses which revealed the significance of regular inspection of bridge structures.

1.2 Scope of the Study

Bridge structures have complex formations, affected by many parameters which are all inter-related with each other. Therefore, inspection should include all of these parameters and the relations among them should be considered in every step. This study deals with the development of an algorithm in context of both structural necessities and the hydraulic constraints. Hydraulic constraints include hydrologic data, hydraulic conditions, and geotechnical aspects. The necessary checklist is prepared for all of these parameters.

The investigation of these items involved in a bridge inspection study would lead to an achievement of rank-based information for the current status of the structure concerned. To this end, existing inspection algorithms are overviewed in view of effectiveness with special reference to the commonly used practices in Turkey and in the USA. A revised checklist is proposed to effectively evaluate the existing situations of bridges in Turkey based on the previous studies, experiences, and practices.

This revised algorithm is interpreted and applied to some existing river bridges around Ankara. The current condition of these bridges is conceived using the proper evaluation methods and calculations which are presented in the subsequent chapters. The main aim of these inspections is believed as to understand the current conditions of the structures not as an individual structure but determine a value; being meaningful when it is relatively compared with other structures. This would help to understand the priority of the necessity of the bridge with respect to maintenance and repair. With the implementation of necessary structural modifications according to the information gathered through a detailed inspection study, the existing safety level of the bridge under consideration would be greatly improved. The aim of the study is renovation of the current inspection system in Turkey, in order to activate it which aims to save primarily human life, economy, and human power.

This thesis is composed of several chapters. The importance and requirement of bridge inspection studies are introduced in Chapter 2 together with the review of related literature. Structural evaluations involved in a bridge inspection study are presented in Chapter 3. Hydraulic evaluations, which need to be carried out for river bridges, are interpreted with reference to the findings of the state of the art studies on this topic in Chapter 4. This chapter also gives the necessary hydraulic measurements, which would provide important clues about the existing hydraulic performance of bridges. The proposed inspection algorithm is presented in Chapter 5. Applications of these algorithms are demonstrated in Chapter 6. The conclusions derived throughout the study are presented in Chapter 7. A sample inspection report is shown in Appendix A. Supplementary photographs are presented in Appendix B.

CHAPTER 2

BRIDGE INSPECTION

A bridge engineer follows the steps of planning, design, and construction in the light of economic and aesthetic aspects. However, after the system starts to function, it is still under the responsibility of the authorities. Once a bridge is constructed, it becomes the property of the owner or agency. The evaluation or rating of existing bridges is a continuous activity of the agency to ensure the safety of the public (Chen and Duan, 2003). Inspection and maintenance are as important and crucial part of the total work as the other steps performed until the structure is set ready for serviceability. The responsibility of an engineer is not only building up a structure but also providing its safe and functioning existence. This necessitates continuous monitoring and inspection of structures, which may gain pronounced importance especially for large hydraulic structures.

It used to be that a great emphasis was placed on bridge construction itself and technical investigation of newly constructed bridges. However, today, examination of measures to safely preserve existing bridges for a long time is required (Ishida et al., 2004). It is believed that constructing new and technologic bridges shows the country's modernization and generally in most countries, except for the most developed countries, the greatest priority of investment is given to the advances of the structure; such as widening, but not to the maintenance of the existing structures. Therefore, inspection has been treated as a secondary task, performed as a result of a warning received from outside sources or from an inadequacy of the structure (Brito and Branco, 2004). In several cases, crises or disasters were the driving force behind initiating maintenance and/or rehabilitation actions, particularly when funds are limited (Abudayyeh et al., 2004). However, the only threat should not only be the total failure but problems occurring in functioning and serviceability must also be checked too.

The design criteria and the conditions predicted during the design stage may show some variations during the life time of the structure. These might sometimes basically because of uncertain conditions of climate, hydraulic properties or natural incidents, deficiencies in structural and geotechnical design phases, deficiencies in materials, whereas in some cases, the reason might be some external and/or artificial effects, such as traffic accidents, sudden impacts, chemical spills, negligence of the daily problems occurring within the bridge, etc. Whatever these circumstances are, the structure should be monitored periodically in order to improve deficiencies such that the structure is ready to take extra loads during a probable extreme future event. Till to the moment that structure becomes apparent and stands up, the work is theoretical. However, these post-construction actions need attention, interest and case-based scenarios. Although the inspection should be based on standardized foundations, it may exhibit variations from case to case according to local conditions.

The primary purpose of bridge inspection is to maintain the public safety, confidence, and investment in bridges. Ensuring public safety and investment decisions require a comprehensive bridge inspection. Within the transportation system, bridges represent a high percentage in terms of added value and replacement cost. Therefore, they need to be managed in a professional manner just like any other asset, and especially so since they strongly contribute to a public service (Brito and Branco, 2004). To this end, a bridge inspector should be knowledgeable in material and structural behavior, bridge design, and typical construction practices. Some of the major responsibilities of a bridge inspector are identifying minor problems, components of the structure that need repairs and unsafe conditions and preparing accurate inspection records, documents, and recommendation of corrective actions, and bridge inspection program support (Chen and Duan, 2003). Now expert systems can handle these duties.

2.1 Bridge Inspection Factors

Bridges are complex structural systems consisting of many different components. Beside the structural obligations, bridges are faced with hydraulic, geographical and natural handicaps. As they need to span distances, they have to stand against natural forces. Because of this composite formation, detailed inspection of various aspects and their interactions should be considered. The overall performance of bridges should be evaluated with respect to these criteria mentioned above, such as structural, geotechnical, hydraulic, and material-based issues. These different aspects should be both controlled individually and compositely. It is more expected to have failure when more than one parameter has problems at the same time, affecting each other.

Bridge inspection practices display changes from country to country according to social, economical, political or even climatic and geographical reasons. However, because of the need to rate bridges under the federally authorized bridge inspection programs to ensure eligibility under federal funding, state agencies have attempted to standardize procedures for evaluating the consequences of deterioration (Xanthakos, 1996). The standardized method is accepted to be the core methodology for the inspection and maintenance schedule. With this core methodology, necessary changes could be applied on, if necessary, according to local needs (Caner et al., 2006).

Inspections should be carried out periodically with definite time periods in order to assess the serviceability performance. National Bridge Inspection Standards (NBIS) in U.S.A. require that each bridge that is opened to public be inspected at regular intervals not exceeding two years. The underwater components that cannot be visually evaluated during periods of low flow should be inspected at an interval not exceeding five years (Chen and Duan, 2003).

The main part of maintenance, management, and operation of bridges is based on the systematic inspection and condition evaluation. It is difficult to evaluate the exact deterioration mechanisms based on the result of a visual inspection.

The examination of old structures constitutes quite a high percentage of the practice of some bridge specialists. For an engineer, it is believed that designing is more interesting and satisfactory than being responsible from the inspection. However, regular inspection is a very hard and important task that needs experiences, carefulness, alertness, and integrity of the engineer. At least one experienced bridge engineer should take part in an inspection team.

The high costs associated with preserving the nation’s deteriorating highway infrastructure and the limited funds available for its maintenance require the development of systematic approaches to optimize the bridge maintenance management process. These approaches should be performance-based and generate minimum life cycle cost, extended service life, and adequate levels of reliability and serviceability (Lounis and Vanier, 1998).

On average, 2.1% of the actual value of each of the 16 OECD (Organization of Eastern Civilization Development) countries’ bridge stock is spent annually on maintenance, repair and strengthening of the bridges (Lounis and Vanier, 1998).

2.2 History of Bridge Inspection: From Past to Today

Structures are one of the symbols of the civilization and an indispensable necessity since the beginning of human life. Throughout time, people had been improved in technology; designed and created different solutions to the needs of human kind. With time, the constructed facilities started to need care and control against deterioration in time and fatigue. Improvements and maintenance become an issue that cannot be neglected. At first, it was assumed not to be a crucial topic to be worked on. Before 1960's, in United States, little emphasis was given to inspection and maintenance of bridges (Chen and Duan, 2003). In 1967, the failure of the Silver Bridge at Point Pleasant in West Virginia, United States, caused 46 people's death and provoked the authorities to focus on this issue (Phares et al., 2000). This created an attention on the safety of the nation's infrastructure and initiated the establishment of National Bridge Inspection Standard (NBIS) in 1971 (Chen and Duan, 2003). These standards had become the guide to show how, with what frequency, and by whom bridge inspection should be applied. Over the past four decades since this tragic accident, the bridge inspection program evolved into one of the most sophisticated bridge management systems in the United States.

In USA, about half of the approximately 600,000 highway bridges were built before 1940 and many had not been adequately maintained till to these shocking experiences that had occurred in Silver Bridge (Chen and Duan, 2003). There is the belief that structures should have adequate capacity for their present loading level. This can be only valid if the design criteria are applied one-to-one to the project without any exception. However, there are always cases of changing details in the construction stage, failure in attaining the necessary concrete strength, unexpected settlements or unforeseen damages to any member of the bridge during the usage (Chen and Duan, 2003). In addition, changing of the weights and volume of the traffic in time with increasing population, and technological improvements are other reasons of these problems. Also, deterioration caused by environmental factors is a growing problem. The live-load-carrying capacity of a bridge structure may have been altered as a result of these deterioration, damage to its members, aging, added dead loads, settlement of bents, or modification to its structural member. According to Federal Highway

Administration in USA, 27.5% of the bridges are deficient within the highway bridge network when bridges are weighted equally. By the word deficiency, both structural deficiency and functional obsolescence are embraced.

2.3 Failure Reasons and Statistics

The principal causes of bridge failures were catagorized as deficiencies in design, detailing, construction, maintenance, use of materials and inadequate consideration of external events. The first four deficiencies represent integral roles in the building of a bridge (Wardhana and Hadipriono, 2003).

In one of the studies (Wardhana and Hadipriono, 2003), with the observation of over 500 failures of bridge structures in the United States between 1989 and 2000, the most frequent causes of bridge failures were attributed to floods and collisions. The overwhelming number of external events, both natural and man-made, representing 83% of all principal causes triggered the bridges to fail. Nature-induced external events include floods, earthquakes, fires, ice, and hurricanes. Floods represents 53% of all failures alone. On the other hand, the human-induced external events that constitute 20% of all failures include bridge overloads and lateral impact of land and marine vehicles on bridges (Wardhana and Hadipriono, 2003).

2.4 Visual Inspection

Bridge inspection, in basic terms, is simply an educated assessment and extrapolation of the condition of a bridge. Bridge inspectors have a wide variety of tools that help them to complete these inspections more accurately, efficiently, and reliably. However, even though many highly sophisticated evaluation tools may be available, the most common means of evaluating a bridge is to simply assess the condition visually (Phares at al., 2000).

Bridge monitoring and inspection are expensive, yet they are essential tasks in maintaining a safe infrastructure. The primary method used to monitor bridges is chosen as visual inspection. During a typical bridge inspection, various components of a bridge are examined at close range by trained inspectors, who evaluate the condition of the components and give them a condition rating (Abudayyeh et al., 2004).

In these inspections, detailed visual observations should be supplemented by some in-situ measurements. Visual observations comprise checking and evaluation of most of the structural components such that a general impression for the current situation of the bridge concerned is achieved. When visual inspection is not sufficient, some instruments may also be used to carry out some in-situ tests.

Routine inspections are regularly scheduled inspections to determine the physical and functional condition of a bridge. They are typically completed using only the visual inspection (VI) technique and rely heavily on subjective assessments made by bridge inspectors (Phares et al., 2004).

The subjectivity is inevitable in visual inspection because of the perception differences of the inspectors. Due to the subjective nature of this evaluation, ratings of the conditions of similar bridge components can vary widely from inspector to inspector and from state to state (Abudayyeh et al., 2004). The inconsistency in the judgment does not even have to be because of different individuals but judgmental vision differences according to daily changes in one person. In order to prevent or minimize human-induced errors, inspections should be rated with great care, parameters should be prepared as objective as possible and performed by an experienced team (Caner et al., 2006).

Especially in concrete assessment, several nondestructive techniques are available. Mainly they are classified into two: visual and non-visual inspections. In visual inspection deterioration is initially assessed visually, and the results are reported on standard forms, supplemented by photographs and sketches of significant sections. On the other hand, in non-visual methods, inspection of closed cells and inaccessible areas may be supplemented by drilling holes to expose areas suspected of being defective (Xanthakos, 1996).

A comparative summary of test methods is studied and presented in Table 2.1. This table suggests that a good visual survey supplemented by a careful selection of techniques to investigate possible defects provides a good approach (Xanthakos, 1996).

Table 2.1 Capability of Investigating Techniques for Detecting Defects in Concrete Structures and Filed Use (Xanthakos, 1996).

TECHNIQUE	CRACKING	SCALING	CORROSION	WEAR AND ABRASION	CHEMICAL ATTACK	VOIDS IN GROUT
Visual	G	G	P	G	F	N
Hardness	N	N	P	N	P	N
Sonic	F	N	G	N	N	N
Ultrasonic	G	N	F	N	P	N
Magnetic	N	N	F	N	N	N
Electrical	N	N	G	N	N	N
Chemical	N	N	G	N	N	N
Nuclear	N	N	F	N	N	N
Thermography	N	G	G	N	N	N
Radar	N	G	G	N	N	N
Radiography	F	N	F	N	N	F
Air Permeability	N	N	F	N	N	F

G: good; F:fair; P:poor; N: not suitable

2.5 Inspection Types

The inspection system is composed of different types of inspections, applied due to the condition and situation of the structure. The components and the interest points change among these types.

2.5.1 Inventory Inspections

It is the first inspection of a bridge when it is constructed. It shows that the structure is taken into the bridge inventory system. The elements of an inventory inspection may also apply when there has been a change in the configuration of the structure. It is a fully documented investigation performed by people, meeting the required qualifications for the inspection (AASHTO, 1989).

The purpose of this inspection is two fold: First, it is used to determine all data for Structure Inventory and Appraisal required by the Federal Highway Administration (FHWA) and all other relevant information (AASHTO, 1989). The second important aspect of the inventory inspection is the determination of baseline structural conditions and the identification and listing of any existing problems or locations in the structure that may have potential problems.

The other inspections during the lifetime of a structure are useless if this primary database is not established.

2.5.2 Routine Inspections

Routine inspections are regularly scheduled, intermediate level inspections consisting of sufficient observations and/or measurements to determine the physical and functional condition of a bridge, to identify any possible developing problems and/or change from “Inventory” or previously recorded conditions and to ensure that the structure continues to satisfy present service requirements (AASHTO, 1989).

Routine inspection is based almost exclusively on direct visual observation that seems to be the diagnostic method with the greatest potential. A period of 15 months between routine inspections is recommended so that the influence of the weather on the general condition and degradation of the bridge can be evaluated (Brito and Branco, 2004).

The personnel required for routine inspection do not have to be overspecialized, but some field experience is advisable. The team typically consists of two individuals. The equipment to be taken to the site include markers, tape-measures, hammer, portable lantern, photo and video cameras, binoculars, etc. (Brito and Branco, 2004).

The results of a routine inspection are to be fully documented with appropriate photographs, properly referenced and scaled and a written report that includes any recommendations for maintenance or repair.

2.5.3 Damage/Structural Inspections

Damage and structural inspections are unscheduled inspections to assess structural damage resulting from environmental or man-inflicted causes; detected during a routine inspection. The scope of inspection must be sufficient to determine the need for emergency load restrictions or closure of the bridge to traffic and to assess the level of effort necessary to affect a repair (AASHTO, 1989).

The inspection team is to be led by an experienced engineer who is an expert with a great deal of knowledge on bridges of the structural type to be inspected and the materials and construction. The equipment necessary for a structural assessment may be non-portable, expensive, and difficult to move. For each situation, the range of recommended equipment is quite variable that is why no specific list can be presented (Brito and Branco, 2004).

2.5.4 In-Depth Inspections

In-Depth Inspections are close-up, hands-on inspections of one or more members above or below the water level to detect any deficiency not readily visible using routine inspection procedures. Personnel with special skills, such as divers and riggers may be required.

This type of inspection can be a scheduled supplement to a routine inspection, though generally at a longer interval, or it may be a follow-up for damage or inventory inspections.

2.5.5 Interim Inspections

This is an inspection scheduled at the discretion of the individual in response charge of bridge inspection activities. It is used to monitor a particular known or suspected deficiency and can be performed by any qualified person familiar with the bridge and available to accommodate the assigned frequency of investigation.

2.6 Reporting

Together with the inspection, there should be a report to be prepared and archived for every bridge. Although there are lots of varieties among these reports of different governments and countries, the main theme is the same: As a general concept, it can be stated that the inspection reports include the inventory data, main parameters to be observed, and grading and evaluation steps.

Inspection reports are required to establish and maintain a bridge history file. These reports are useful in identifying and assessing the repair requirements and maintenance needs of bridges. NBIS requires that the findings and results of a bridge inspection be recorded on standard inspection forms (Chen and Duan, 2003).

Descriptions in the inspection reports should be specific, detailed, quantitative, and complete. Narrative descriptions of all signs of failure, or defects with sufficient accuracy should be noted so that another inspector can make a comparison of condition or rate of disintegration in the future. The seriousness and the amount of all deficiencies must be clearly stated in an inspection report. Photographs and sketches are the most effective ways of describing a defect or the condition of structural elements. It is, therefore, recommended to include sketches and/or photographs to describe or illustrate a defect in a structural element (Chen and Duan, 2003).

Each bridge document needs to have items, such as structure information, structural data and history, description on and below the structure, traffic information, load rating, condition and appraisal ratings, and inspection findings. The report documented after the inspection should enclose the previous and current conditions of the structure and the original design parameters. This information is necessary in order to understand the problem in a wider range and create an efficient countermeasure (Chen and Duan, 2003).

The inventory part includes the basic information about the structure. What is meant with basic information is the name, location, designer-constructor information, completion date, last inspection date, etc. This can be accepted as the ID card of the structure concerned. In this part, also the environmental data are given as being a river bridge, a highway bridge or a crossway bridge. This part is completely an informative section about the structure in order to give as much information as possible to the engineer when he/she first met with the structure.

The second part consists of the parameters that are obtained in the site and to be evaluated. Every topic does not have to be the same in every report. However, the main sections and major elements are constant in most reports. Structural section is more dominant than any other which is followed by hydraulic and ground related parameters.

The grading system is an inconsistent understanding in these reporting. Some system prefers verbal evaluation, whereas there are mathematical systems and numerical evaluation levels in many of these. Numerical assessment is a better way to judge as after the at-site evaluation, the rest can be done with a calculative method. With a quantitative result, it would be easier to compare the structures and understand the conditions and criticality.

To reduce the subjectivity of reports and conclusions drawn from inspections, a standard classification system must be devised containing the following items: defects, their possible causes, current repair techniques, and diagnostic and surveillance methods (Brito and Branco, 2004).

2.7 Bridge Inspection Practices

Every government accepts different inspection methodologies or reporting systems. Despite having common points among these, there also exist some conflicting differences.

2.7.1 Current System Used in USA

Being consisted of many states with different rules and regulations, there is no single inspection system or checklist to be applied in the United States. Every state's transportation department organizes a self-fitting method and provides the necessary inspection and precaution method.

In order to cope with the complex inspection concept, in addition to constituting the experimental part, the interpretation and the plans of action should be applied. Plan of action can be even taken as one independent topic as there are different cases having variable situations and necessities.

Federal Highway Administration in the United States works on the concept of plans of action to the scour-critical bridges and the necessary countermeasures with an intense study. The bridges are classified according to their priority of maintenance and different plan of action scenarios are derived for every bridge according to their sensitivity to damage and deterioration (ITD, 2004). The alternate scenarios change according to the economic risk of bridge failure and the annual probability of failure.

Long Island Rail Road Bridge Inspection Report is a practical example to currently used inspection process in the United States. It consists of seven numerical grading levels with four main and three sub grades. In this system, odd numbers are the main four levels defined and even numbers are the sub levels to be used if the situation is stuck in the middle. One other necessary point to be resolved is the calculation and the conclusion of the inspection. There are a lot of parameters in different sub-groups (PBQD, 2003).

2.7.2 Current System Used in Turkey

In Turkey, KGM (General Directorate of Turkish Highways) is the corporation that is responsible from repair and maintenance of bridges. The responsibility consists of the design stage before construction, the construction stage itself, and the subsequent stages of inspection and maintenance.

The studies on the subject are derived and collected in the manual of Visual Bridge Inspection of KGM (KGM, 1999). It has been stated that the main aim of this handbook is to provide information for the bridges in all regions of the country with a common sense of understanding. All the bridges are aimed to be open to traffic, providing the design conditions of the structure through the life time with safe traffic conditions and necessary precautions for the natural disasters.

It is composed of three main parts, shown in Table 2.2: the inventory part, evaluation part and part of repair record. The inventory part is the part that should be completed before visiting the field. The information about the river bridge concerned should be completed and updated periodically including high flow seasons. The bridge traffic data should be collected from the related department.

In the second part, the sub elements of the structure and the probable symptoms are displayed. The inspector should evaluate the conditions of these symptoms with one of the grading levels of A, B, C, and D. The grading scale used is as follows: A: Need urgent maintenance, B: Need maintenance, C: Need continuous inspection, D: No damage.

The third part is filled in the office according to the previous repairs applied to the structure. In order to evaluate the current condition, the inspector should know the history of the structure.

The personal opinion of the inspector is the dominant factor in the determination of the damage of the structure. Therefore, objectivity should be maintained with necessary explanations in order to have a consistent inspection among different inspectors.

Table 2.2 Visual Inspection Information Form (KGM,1999).

General Information	Bridge Name		Spans			
	Region #		Road Width			
	Division #		Border Width			
	Name of river		Angle of obliquity			
	Project Specification and Load Class		Construction Firm			
	Bridge Length		Year of Construction			
Superstructure	Type of bridge		Type of deck/floor			
	Type of support		Type of coating			
	Type of superstructure		Type of railing			
	# of beams		Joint Type			
River Conditions	Low water depth		High water depth		Water velocity	
	Low water width		High water width		Depth above waterlevel	
Soil Condition	Topography		Soil Structure		Land Use	

AADT		Bus				Truck				Pickup truck				Car		Total	
EVALUATION	***Coating***	Waving		Tire tracks		Cracks		Holes and cavities								OVERALL SCORE	
	Border and Railing	Cracks in the concrete		Concrete Disintegration		Apparent Reinforcement		Deofrmation in railing		Rusting in railing		Deficiency in railing				OVERALL SCORE	
	Drainage	Pipe Damage		Blockage		Cleanout										OVERALL SCORE	
	Expension Joint	Noise		Water leakage		Deformation		Holes and cavities		Loss of elements						OVERALL SCORE	
	Deck	Cracks		Concere Disintegration		Appereant Reinforcement		Holes and cavities		Water leakage						OVERALL SCORE	
	Metallic Support	Main Damage		Loss of elements		Anchorage		Support bed								OVERALL SCORE	
	Elastomeric Support	Surface Arrangement		Deformation		Support bed										OVERALL SCORE	
	Steel Beams	Deformation		Cracks		Rusting		Bolts and Rivets								OVERALL SCORE	
	Concrete Beams	Deformation		Cracks		Concrete Disintegration		Apparent Reinforcement		Holes and cavities						OVERALL SCORE	
	Abutment	Deformation		Cracks		Concrete Disintegration		Apparent Reinforcement		Holes and cavities		Water and debris abrasion		Scour in foundation		OVERALL SCORE	
	Pier	Deformation		Cracks		Concrete Disintegration		Apparent Reinforcement		Holes and cavities		Water and debris abrasion		Scour in foundation		OVERALL SCORE	
	Approach Fill	Settlement and slump		Erosion on road platform		Erosion in fill										OVERALL SCORE	
	Stabilization	Settlement and slump		Erosion		Scour in bed level										OVERALL SCORE	
DAMAGE INDEX	***Emergency Index***																
	Importance Index																

REPAIR RECORDS	***Structure Elements***	Date of Repair	Class of repair	Procedure of repair	Cost
	Coating				
	Border and Railing				
	Drainage				
	Expension Joint				
	Deck				
	Metallic Support				
	Elastomeric Support				
	Steel Beams				
	Concrete Beams				
	Abutment				
	Piers				
	Approach Fill				
	Stabilization				

A: Urgent Maintenance B: Need Maintenance C: Continous Inspection D: No damage

The parameters affecting the structure are ordered according to their influence priority to the structure. This priority list of KGM methodology is as follows:

1. Effects on the safety of vehicle and pedestrian traffic.
2. Indirect effects on the safety of traffic as trouble in driving conditions.
3. Indirect effects on the safety of traffic as a slow down in traffic speed.
4. Effects on the load capacity of structural elements of the bridge.
5. Examination of possible decrease in the economical life of the structural elements.
6. Examination of decrease in the comfort of the pedestrians or vehicle traffic
7. Examination of any kind of disturbance to the ones that are not using the structure.

CHAPTER 3

STRUCTURAL EVALUATION

Bridge structure is a complex formation of many parameters. In order to constitute a systematic inspection algorithm, it is hard and complex to establish a system covering all the structure as a whole. The structural aspect of bridges is the dominating factor. The parameters related with these structural aspects should be well-organized and the relationship among them should be placed well in the system.

There are lots of parameters to be observed. Some can be defined as superstructure, such as deck, abutment, etc., whereas there are the others, defined as supporting structure, such as piers or supports.

These parameters that constitute the structure when combined are mainly grouped among themselves in order to realize the duties and importance in inspection and/or evaluating.

3.1 Main Body Components

Main Body components typically are the skeleton of the structure, which have the main responsibility of the load transfer. They are the compulsory elements and any problem occurring at these elements should be monitored and repaired immediately.

3.1.1 Deck

The materials used for deck elements vary. The primary preferences for material selection are steel, timber, or concrete. Every material shows different behavior against loading and the deformation symptoms vary according to material changes. Therefore, even the evaluation scale does not change with this difference, the countermeasures to be implemented or the sensitivity of the material to the deformation changes.

In steel decks, the common expected problems are cracked welds, broken fasteners, corrosion, and broken connections. In a corrugated steel flooring system, section loss due to corrosion may affect the load-carrying capacity of the deck and thus the actual amount of remaining materials needs to be evaluated and documented. In timber decks there can be some different defects, such as crushing of the timber deck at the supporting floor system, flexure damages, e.g. splitting, sagging, and cracks in tension areas, and decay of the deck due to biological organisms, especially in the areas exposed to drainage (Chen and Duan, 2003).

The most common material used in bridge structures is concrete. Therefore, the most important case should be the problems within these concrete decks. They are wear, scaling, delamination, spalls, longitudinal flexure cracks, transverse flexure cracks in the negative moment regions, corrosion of the deck rebars, cracks due to reactive aggregates, and damage due to chemical contamination. The importance of a crack varies with the type of concrete deck. A large to medium crack in a non-composite deck may not affect the load-carrying capacity of the main load-carrying member. On the other hand, several cracks in a composite deck will affect the structural capacity. Thus, the inspector must be able to identify the functions of the deck while inspecting it (Chen and Duan, 2003).

The evaluation form is prepared with the essence of concrete decks being in majority. When to inspect the structure, observation starts with examining the cracks or disintegrations existing in concrete. Then, there should be the check to see if there is any apparent reinforcement, holes and cavities or water leakage from the deck.

3.1.2 Beams

Beams are one of the other crucial and fundamental elements within the structural arrangements. Loads imposing to the deck are transferred to the supports by beams. Therefore, they can be stated as one of the main elements of the structural system. The two main types are as follows:

3.1.2.1 Steel Beams

Beams constructed with steel plates or with truss system are all counted as steel beams and evaluated with the same perspective.

During the inspection, primary observation is for detecting if any visually perceived deformation exists within the beams. Then the existence of any cracks or rusting is searched. Bolts, rivets and welding are the other important elements to be checked in steel beams (KGM, 1999).

3.1.2.2 Concrete Beams

All types of concrete beams, whether reinforced or prestressed, are all evaluated in the same type with the same parameters to be considered. The primary concern is the existence of any deformation of the elements that can be observed visually and occurred because of some manufacturing errors, overloading, aging or striking.

There can also be some cracks on concrete beams. Because of cracks, air and water pass through beams and give damage to the reinforcement. Any kind of concrete disintegration should also be inspected and graded. The reinforcement that becomes apparent to naked eye is another point to be observed. Finally, holes and cavities occurring within the beams should be graded (KGM, 1999).

3.1.3 Supports

Supports are the elements that connect the structure to the ground. They transfer the load from beams to the ground. According to the construction material, they are classified into two as metallic and elastomeric supports.

3.1.3.1 Metallic Support

Metal bearings sometimes become inoperable (frozen) due to corrosion, mechanical bindings, buildup of debris, or other interference (Chen and Duan, 2003).

The parts to be inspected in metallic support are primarily the main damages which are any cracks, broken points, excessive rotation, causing disintegration of the support with the main deck. Then it should be checked whether there is loss of elements due to breaking and smashing into pieces. The anchorage between the support and beam might have deficiencies because of fatigue, worn out or excessive usage of the material. As they serve to receive the load from the superstructure and transfer to substructure, the problem might cause great deficiencies.

3.1.3.2 Elastomeric Support

Damage in elastomeric bearing pads is excessive bulging, splitting or tearing, shearing and failure of bond between sole and masonry plate (Chen and Duan, 2003).

Since the damage of the bearings will affect the other structural members, repair of bearings of any kind needs to be considered as a preventive measure, even though the problem is not urgent.

With elastomeric supports, after looking for main damages as in metallic support, the surface arrangement is checked. The metallic surface might be cracked because of aging, worn-out, etc., or the loss of adherence among the metallic surfaces causes the plates to become apparent and get rusted. There might also some identification of deformation or damage in the support bed and necessary inspection should be graded (KGM, 1999).

3.1.4 Piers

Piers are assigned for carrying the load from the structure to the ground. According to the topography of the site, they can be located on dry soil or in water. As river bridges comprise the majority among all bridges, piers are generally believed to be in relation with hydraulic conditions. This fact brings the problem of scouring, accumulation of bed material, etc., to the evaluation of element. As they are the free standing structures and they carry a serious amount of load, any kind of deformation or deficiency may create great problems and serious results.

During the design, number of piers should be limited with the minimum requirement, in order to decrease the contact of the structure with water. If the stream is narrow enough, it is mostly preferable not to have any piers. They are advised to be aligned with flow direction at flood stage in order to minimize the debris accumulation and reduce the contraction effect (Lagasse et al., 2001 (a)).

3.2 Earth Retaining Components

They are the elements that provide the stability of the structure and the connection of the system with its environment. They are physically elements that are apart from the main body. However, their absence cannot be an option. Any problem should be detected and the necessary repairing should be applied.

3.2.1 Abutments

Abutments can be defined as the side supports that are leaned against the soil at the ends of the span of the bridge. They transfer the loads at the ends of the span to the ground. They play a serious role in the load transfer and they are one of the crucial elements within the structure.

There are different types of abutments, such as spill through, vertical wall, or vertical walls with wing walls. Even though they seem to have same factors to be affected, the structural difference causes some difference in the reaction of the structure. Scour at spill-through abutments is about 50 percent smaller than at vertical wall abutments, subjected to the same hydraulic conditions, i.e. scouring actions (Lagasse et al., 2001 (a)).

As the abutments are concrete in majority, the deficiencies are mentioned as they all occur with concrete material. The general points to be checked are similar to beams and other concrete elements. Primarily any deformation, such as settlement, bending, slipping or twisting that can be observed visually is controlled at support junctions, due to overloading, scouring, manufacturing mistakes or striking (KGM, 1999).

The cracks at the head beams of the abutments should be checked. Concrete should also be inspected for any disintegration at these regions. Additionally, reinforcements should be observed to see whether there are any visible regions at which concrete has been spilled. Last thing to be observed is whether there are holes and cavities on the concrete elements.

Most of the deficiencies confronted at abutments are originated from hydraulic oriented problems. For instance, debris transported with the flow may create problems at the bed level and at bridge opening by accumulating and blocking the flow, which also pronounces scouring.

3.2.2 Approach Fill

Approach fill, is the soil stiffing behind the abutments, at the inlet and outlet of the bridge, constructed in order to create a stronger and more secure bracing to the whole structure. They can be considered to have a secondary priority among the elements of the bridge. However, it functions as a kind of foundation of the abutments which stand against the horizontal forces acting on the structure. When a bridge is to be constructed to cross a wide river, approach fills (embankments) may be constructed on both floodplains towards the main channel to reduce the total length of the bridge (See Figure 3.1). In such cases an upstream contraction zone is generated in which flow lines are subject to severe curvature. A dead zone is created with slowly moving reversed eddy. The head sections of the approach embankments need to be protected against scouring at the bed level and at the sides of the embankments. Hydraulic conditions of flow through river bridges, however, are out of scope of this thesis.
The major points to be inspected are primarily limited with settlements of 10 mm depth and slumps of 15 mm height (KGM, 1999). Any kind of erosion at the road platform or at the fill should be under control.

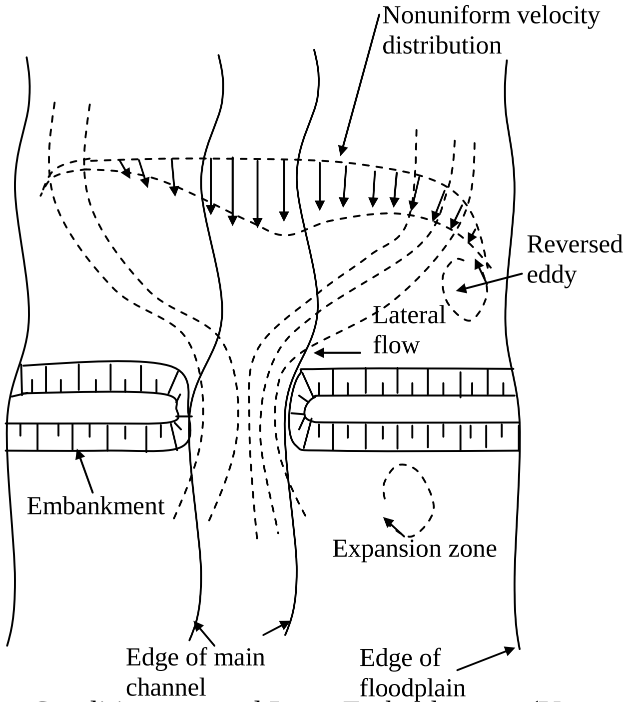


Figure 3.1 Flow Conditions around Long Embankments (Yanmaz, 2002).

3.2.3 Stabilization

Retaining walls, spurs, check dams etc., are the complementary elements of the bridge in order to obtain the safety and strengthening necessities. Retaining walls and spurs are river training facilities intending to improve the condition of flow approaching the bridge. Check dams are small-scale embankments, which are usually constructed at the downstream side of bridges to limit the stream bed erosion. Even if there are no strengthening elements within the structure, it should be reported.

The first point to be observed is occurrence of any settlement or slump within these elements. Then possible erosion tendencies should be checked. Finally, scouring at the bed level should be inspected (KGM, 1999). New types of scour countermeasures which intend to protect the bed or deflect the approach flow can also be implemented if necessary. Details of such applications can be found in Yanmaz (2002).

3.3 Serviceability Components

These components are secondary elements for the stability of the structure. They do not provide the structural standing. However, their existence increases the quality in the usage. It provides comfort and safety to the bridge. Any problem occurring does not need an immediate care. However, the repair needed should not be postponed. Although they are stated as the comfort elements, the usage is dependent on these elements. The functions of these elements are introduced in the following subsections.

3.3.1 Coating

Coating is the cover layer of the road. It is one of the functional elements in the system. The problems in coating primarily affect the usage and cause other future defects with time. The deformations should be determined on time and the necessary improvements should be applied.

The sub branches that help to evaluate coating condition consist of waving, tire tracks, cracks, and holes and cavities. Waving is the deficiency of the coating in the shape of a hunchback, bigger than 15 mm in height. They create wave-shaped deficiencies which are perpendicular to the direction of traffic, mainly occurring with the cause of breaks (KGM, 1999).

Another point to be examined is tire tracks as they cause problems of drainage as the waving similarly does. However, the formed deficiencies with tire tracks are formed in the direction of the traffic. Cracks are formations that are spread to more than 10% of the area of the deck, and are formed because of aging of the coating material, wrong choice of material, or bad climate (KGM, 1999).

The last point to be observed is the holes and cavities. They are described as the holes and cavities bigger than 10 mm height and 30 cm diameter, occurring when a part of the coating material is dislocated.

3.3.2 Expansion Joint

Damage to joint seals is caused by vehicle impact, extreme temperature, and accumulation of dirt and debris. Damage from debris and vehicles, such as snowplows, could cause the joint seals to be torn, pulled out of anchorage, or removed all together. Damage from extreme temperature could break the bond between the joint seal and deck, and consequently result in pulling out the joint seal completely (Chen and Duan, 2003).

The noise from the loosen anchorage, water leakage from the joints that are originally designed as waterproof but lost in time, deformations, holes and cavities, loss of some elements and some functions are the remarkable points to be observed (KGM, 1999).

3.3.3 Drainage

Drainage is a necessary part of the whole structure. Unless it exists, any rain or snow melt will create puddle which will affect the flow of traffic or create chemical deteriorations because of excessive water accumulated. Drainage system provides this water not to accumulate and diverts the flow to an excessive canal where the flow will reach to its way without any destruction.

The sub parameter to be observed here are pipe damage, blockage, and cleanout. Blockage of pipes occurs because of the accumulation of debris and dirt. The problem in any one of these parameters creates the problem of the existence of excess water on the slab (KGM, 1999).

3.3.4 Border and Railing

Border and railings are also functional elements in a bridge structure. They are located at the edges of roads and show the borders of the road in order to provide the traffic in its own lane and to protect any uncontrolled actions in order not to move outside the road. They have also aesthetic concerns. However, especially on highways, the type of material used is very important and should be chosen with great care since it has a direct influence on safety of the road.

The parameters to be observed in order to complete the inspection are cracks and disintegration in the concrete, the apparent reinforcement, deformations, rusting, and deficiencies in railing.

3.4 Other Components

This list is basically made to be used on many bridges of the country. However, it is a fact that all the bridges cannot be constructed with similar methods, materials, and/or elements. Therefore, this fourth group is for the structures that have anything else to be reported. The inspector should do his/her observation on that specific element and add the grade obtained to the overall evaluation.

Applications of these items which are to be inspected according to the structural aspects are illustrated in the case studies in Chapter 6.

CHAPTER 4

HYDRAULIC EVALUATION

Bridges have the responsibility to be able to stand against loads, due to natural causes and artificial reasons. They have a complex formation and a challenging engineering design. Their existence aims to function well and provide safety during the lifetime. Design of bridges is focused on structural requirements and the major challenge has been counted as to be the stability against dead and live loads. However, in river bridges, the hydraulic conditions should also be taken as one of the major concerns during design and during subsequent inspections.

Since bridges are composed of various structural elements, it is not easy to assess the overall current situation. In the case of river bridges, the hydraulic concerns are additional components to increase the complexity. Some hydraulic factors, like excessive scouring at infrastructural elements are of vital importance in affecting the overall safety of the system. On the other hand, the actual level of eroded river bed cannot be detected simply unless some sophisticated instruments are used.

In order to design according to the flow properties, hydrologic conditions of that basin should be searched and analyzed with great care. The hydraulic calculations of the designed structure should be executed and the necessary interrelations among structural, hydraulic, and geotechnical aspects should be checked (Yanmaz, 2002).

If the hydraulic properties are not considered properly in the design, there are a lot of problems occurring, especially during the flood season. Common problems are as follows (Yanmaz, 2002):

- The foundation of the footing is not located as deep as it should be. This will be the reason of bridge failure induced by scouring in a very short time.
- The dynamic force applied to piers by large rocks and stones, which are carried with flood, is an effective load on the structure.
- The accumulation of debris composed of tree stems and branches at the pier openings causes the blockage of the opening. Hence it causes reduction in net flow area and increases scouring potential.
- The accumulation of bed material at the opening because of natural river regime.
- The erosion of the unprotected slopes of bank facilities causing collapses at the foundation of abutments.
- The erosion at the slope of the approach fill in the long spanned bridges, etc.

In the classical bridge design approach, the main concept is concentrated on structural design aspects. The slab and the load bearing system are resolved to be able to carry the maximum possible load to be transferred. Sometimes, the structure is planned to stand to very excessive amounts in order not to face with any problems. However, this might create problems from hydraulic points of view. For instance, structurally overdesigning causes large piers and thick slabs. This means having the pier openings narrower and the flow cross-section getting smaller. This is a disadvantage for the flow and for the structure, as it pronounces scouring, increases backwatering, or may even cause hydraulic jump through bridge opening (Yanmaz, 2002).

Bridges passing over waterways, especially rivers and streams, may cause major maintenance difficulties. These bridges are susceptible to scour of the riverbed. When the scoured riverbed elevation falls below the top of the footing, the bridge is referred to as scour critical (Chen and Duan, 2003).

Critical scouring does not have to occur at the maximum flow conditions. However, design of the structure and the environmental arrangements should be arranged to withstand the maximum conditions (Yanmaz, 2002).

Identifying spatial and temporal trends of channel adjustments are important for the protection and maintenance of bridges (Johnson, 2005). Some bad experiences of bridge failures due to stability problems warned the authorities to give more importance on the subject and create an inspection system on the stability of the river bed and foundations.

In order to prevent the probable deficiencies to occur within the structure due to stability problems, there should be a successful assessment procedure to apply. River bridges are the most frequent types among all bridge types in many countries. The sufficient time to be spent on one bridge's detailed inspection cannot be met within a proper inspection; because only limited amount of time can be spent to each bridge. On the other hand, a detailed inspection of a bridge and the stream beneath might help to identify any problem and necessary interference is applied according to the criticality of the situation (Johnson, 2005).

4.1 Existing Channel Stability Assessment Methods

There are a few of different methods to assess the stability condition of the river. Some are in a more complicated formation; whereas, there are some, formed with simpler concepts and methods. The aim for all of these stabilization checks is the same which is to assess the current condition of the channel at a reach scale or over the entire watershed system (Johnson, 2005).

Hydraulic Engineering Circular 20 (HEC-20: Stream Stability at Highway Structures) is a manual to assess channel stability and potential stability-related problems in the vicinity of bridges and culverts. A three level approach is suggested that covers geomorphic concepts and qualitative analysis, hydrologic, hydraulic, and sediment transport concepts; and mathematical or physical modeling studies (Lagasse et al., 2001 (a)).

The U.S. Army Corps of Engineers also suggest a similar three-level stability analysis for the purpose of stream restoration design. Their description for this analysis is very similar to the previous one. They define level 1 as a geomorphic assessment, Level 2 as a hydraulic geometry assessment, and Level 3 as an analytical stability assessment that includes a sediment transport study (Johnson, 2005).

Johnson et al. (1999) developed a rapid stability assessment method based on geomorphic and hydraulic indicators that have been included in the most recent revision of HEC-20. This provides a systematic method for a Level 1 analysis and is used to determine whether it is necessary to conduct a more detailed Level 2 analysis. Thirteen qualitative and quantitative stability indicators are rated, weighted, and summed up to produce a stability rating for gravel-bed channels. The method was based largely on prior assessment methods. Its primary limitation is that it was developed from and tested on a limited number of sites in the Piedmont and glaciated Appalachian Plateau regions of Maryland and Pennsylvania, thus limiting its applicability in other regions of the country (Johnson, 2005).

Rosgen (see Johnson, 2005) proposed a channel stability assessment method that is based on assessing stability for a stable reference reach and then the departure from stable conditions on an unstable reach of the same stream type. The stability analysis consists of 10 steps that assess various components of stability. The steps include measurement or description of:

1. The condition or “state” categories
2. Vertical stability in terms of the ratio of the lowest bank height in a cross-section divided by the maximum bankfull depth

3. Lateral stability as a function of the meander width ratio and a bank erosion hazard index
4. Channel pattern
5. River profile and bed features
6. Width-depth ratio
7. Scour and fill potential in terms of critical shear stress
8. Channel stability rating using a modification of the Pfankuch method (see Johnson, 2005)
9. Sediment rating curves
10. Stream type evolutionary scenarios

4.2 Stability Assessment Indicators

In the inspection process, from hydraulic point of view, the parameters observed are targeted to assess the stability of the ground and river bed. The hydraulic-related problems can be evaluated by assessing channel stability. A stable channel in the vicinity of a bridge is defined as the one in which the relationship between geomorphic process and form is stationary and the morphology of the system remains relatively constant over a defined distance upstream and downstream from bridge, and with minimal lateral movement (Johnson, 2005).

A stability assessment procedure for bridge applications should have the following characteristics (Johnson, 2005):

- It should be brief so that it can be completed rapidly.
- It should be simple in that extensive training is not required (although some training will likely be required)
- It should be based on sound indicators.
- It should be based on the needs of the bridge engineering community.

During this assessment, it is suggested that spatial bias in stability can be reduced by walking a distance well upstream and downstream of the project reach, while temporal bias can be reduced by revising the site at different times of year (Johnson, 2005). The brief interpretations of the parameters in this form are explained below.

4.2.1 Bank soil texture and coherence

It describes the soil type of the bank. According to the type of the soil, the cohesiveness is determined and evaluated. These are important points for the stability as all the system is established on this ground. Settlement and other foundation related problems occur primarily because of the wrong or missing knowledge about the soil material. Without knowing the necessary items, none of the design steps might start.

4.2.2 Average bank slope angle

It is the angle of the slope of the bank. It is defined as the ratio of the horizontal (H) to the vertical (V). It indicates the potential of the bank to move downwards for any reason. The higher this ratio is, the more problems might occur on the stability. Although the necessary calculations are done during design and construction; hydrologic and frictional factors combining with the usage conditions, the morphology of the land changes.

4.2.3 Vegetative bank protection

Vegetation is probably the most natural method for protecting stream banks. It is not only less expensive than other protective alternatives but also improves environmental conditions (Julien, 2002). The root system helps to hold the soil together and increase overall bank stability by forming a binding network. Additionally, the exposed stalks, stems, branches, and foliage provide resistance to the stream flow, causing the flow to lose energy by deforming the plants rather than by removing soil particles (Julien, 2002). It is important to choose plants that are native to the region and durable to flooding, at least for mild ones.

There also exists some disadvantages of vegetation, e.g., they may cause some undermining, might be uprooted because of freezing and thawing, need a constant and fixed wetting and drying, etc.

4.2.4 Bank cutting

River does not always flow through its original bed. Some straightening and/or meandering are created. Especially, when the velocity is increased, water tends to flow in the straightest direction; therefore it changes its stream bed. This might cause the river to interrupt the bank, for some amount. That destroys the stabilization in the bank and may create some problems.

4.2.5 Mass wasting or Bank Failure

Mass wasting, also known as mass movement or slope movement is the geomorphic process by which soil, regolith, and rock move downslope under the force of gravity where regolith is a layer of loose, heterogeneous material covering solid rock (Wikipedia, 2006).

When the gravitational force acting on a slope exceeds its resisting force, slope failure (mass wasting) occurs. Mass wasting may occur at a very slow rate, particularly in areas that are very dry or those areas that receive sufficient rainfall such that vegetation has stabilized the surface. It may also occur at very high speed, such as in rock slides or landslides, with disastrous consequences (Wikipedia, 2006).

4.2.6 Bar Development

A bar is defined as an elongated deposit of alluvium within a channel, not permanently vegetated (Lagasse et al., 2001 (a)). In other words, they are the accumulation of small, island-like soil heaps, formed at the stream. Scouring is a very major phenomenon occurring at the piers of bridges. When the soil is taken out by the hydraulic force in scouring, it is carried for a while and then accumulated when the water does not have the enough energy to carry. Bar development occurs at these points.

If the concave bank at a bend is eroding slowly, the point bar will grow slowly and vegetation will become established on it (Lagasse et al., 2001 (a)).

4.2.7 Debris Jam Potential

Debris is defined as the floating and submerged material, such as logs, vegetation, or trash, transported by stream (Lagasse et al., 2001 (a)). Their separate transportation may not influence the flow and the stabilization. However, when these are gathered, they might block the pier openings or accumulate near the piers. Then this will affect the flow and stabilization in negative way. They can direct the flow to take place in a narrower area or flow may be deflected away from its original bed. The result of debris accumulation is increased scouring potential at the bridge site. With periodic maintenance, especially after heavy floods, debris accumulation should be removed to offset negative effects.

4.2.8 Obstructions, Flow Deflectors, and Sediment Traps

They are the structural or solid obstructions that are present through the stream bed. They are formed for other purposes, such as to divert the flow or to govern the sediment transportation. However, they might cause some disadvantages, such as converting the flow out of the stream bed or losing the control of the stream. They also disturb the flow by changing the direction and make the flow lose its uniformity.

4.2.9 Channel Bed Material Consolidation and Armoring

Consolidation is stated as the gradual, slow compression of a cohesive soil due to weight acting on it, which occurs as water, or water and air are driven out of the voids in the soil. It only occurs with clays or other soils of low permeability (Scott, 1987). HEC-20 manual defines armoring as the surfacing of channel bed, banks, or embankment slope to resist erosion and scour (Lagasse et al., 2001 (a)).

These two concepts provide means to assess the stability level of the river bed. Therefore, their presence helps the structure to stand due to the hydraulic forces.

4.2.10 Shear Stress Ratio (τ_o/ τ_c)

Shear stress ratio can be used to indicate stability. The shear stress ratio on the channel bed is the ratio of the average boundary shear stress to the critical shear stress for entrainment of bed material load and can be defined as $\tau_e = \tau_o / \tau_c$ where τ_e: shear stress ratio, τ_o: average boundary shear stress and τ_c: critical shear stress at which bed material particles begin to move (Johnson et al., 1999).

The average boundary shear stress in uniform open channel flow is defined as $\tau_o = \gamma RS$ where γ is specific weight of water, R is hydraulic radius, S is channel bed slope. The critical shear stress, τ_c , can be determined from Shields criterion using relevant bed material properties.

4.2.11 High Flow Angle of Approach to Bridge or Culvert (α)

The way the river approaches to the structure is important. The most preferable case is the structure to be constructed perpendicular to the flow so that the projected width of piers perpendicular to the flow direction cannot reduce the flow area drastically. Angle of approach flow may be reduced by implementation of proper guiding walls and spurs at immediate upstream of the bridge.

4.2.12 Bridge or Culvert Distance from Meander Impact Point (D_m)

As the approach angle has just been stated as an important parameter for the structure, the distance of the structure with any meandering, if exists, is also very crucial. If enough space can be maintained between the meandering and the structure, naturally river would try to find a straight way to head up to the bridge. Otherwise, the flow would create similar problems as in the case of oblique approach flow conditions on the river bank.

4.2.13 Percentage of Channel Constriction (M)

Constriction is a natural or artificial control section, such as a bridge crossing, for which the total width of the river is contracted by the infrastructure elements, i.e. piers and abutments.

Contraction is one of the major reasons of scouring. It decreases the cross-sectional area and causes an increase in velocity. That motivates the increase in shear stress at bed level.

4.3 The Evaluation Methodology and Assumptions

There are several assumptions implied in this method (Johnson, 2005). First, this method implies that each indicator is independent of all others. While it is possible that some correlation exists between several indicators, an attempt is made to select indicators that independently describe various aspects of channel stability; thus, correlation effects are assumed to be insignificant.

Secondly, the summing of the ratings assigned to each indicator implies a linear relationship between the channel stability and the selected indicators. Given that weighted ratings provided no change in the overall results, it can be assumed that the linearity will also not affect the results significantly.

4.4 Scour Monitoring and Instrumentation

Scouring is one of the biggest threats of river bridges. Many failures occur because of stability failure as a result of scouring. The inspections should include a wide branch for this kind of monitoring. Visual monitoring for scouring during the flooding is hard to manage. Therefore, using some instruments may solve this problem. There are two kinds of instruments which are classified as portable and fixed.

These two types of instrumentations are not exchangeable. Both have different advantages and disadvantages; and are used for different purposes. Fixed instrumentation is used with frequent measurements or regular monitoring. However, portable instrumentation would be preferred when only occasional measurements, such as flooding, etc., are needed (Lagasse et al., 2001(b)).

There are also sub groups for the kinds of instrumentation within fixed and portable instrumentations. There should be a conscious plan of action for choosing and using the accurate instrument for the case. Selection of the appropriate instrumentation will mainly depend on site conditions and operational limitations of specific instrumentation.

The basic concerns in the selection of the right instrumentation is based on the number and location of the instruments for fixed instrumentation since it may not be practical or economical to instrument every pier and abutment. For portable instrumentation, the frequency of data collection and the detail and accuracy required will have to be defined, as it may not be possible to complete detailed bathymetric surveys at every pier or abutment during every inspection (Lagasse et al., 2001 (b)). These instrumentations are explained in the following subsections.

4.4.1 Portable Instrumentation

Portable instrumentation is typically used when a fixed instrument has not been installed at a bridge; or when it is necessary to supplement fixed instrument data at other locations along the bridge. The use of portable instruments during low-flow conditions has been very successful; however, their success during flood conditions, when the worst scour often occurs, has been more limited. Portable instrumentation is an important part of a scour monitoring program. A portable scour measuring system typically includes four components (Lagasse et al., 2001 (b)): a) Instruments b) Deploying the instrument(s), c) Positioning, and d) Data storage.

4.4.1.1 Instruments

They are grouped into three: physical probing, sonar, and geophysical.

i. Physical Probing: Physical probes are the devices that can be used within the reach of the inspector. The most common examples are sounding poles and sounding weights. Sounding poles are long poles used to investigate the bottom. Sounding weights are typically a torpedo shaped weight suspended by a measurement cable. This category of device can be used from the bridge or from a boat. An engineer diver with a probe bar is another example of physical probing (Lagasse et al., 2001 (b)).

Physical probes only collect discrete data and can be limited by depth and velocity or debris and/or ice accumulation. Advantages of physical probing include not being affected by air entrainment or high sediment loads, and it can be effective in fast, shallow water. The use of physical probes is generally limited to smaller bridges and channels (Lagasse et al., 2001 (b)).

ii. Sonar (Sound Navigation and Ranging): They measure the elapsed time that an acoustic pulse takes to travel from a generating transducer to the channel bottom and back. Sonar can be adversely impacted by high sediment or air entrainment (Lagasse et al., 2001 (b)).

Portable sonar instruments may be better suited for large bridges and channels, but they can also be limited by flow conditions based on the deployment options available. Sonar may also be limited in high sediment or air entrainment conditions, or when debris or ice accumulation are present (Lagasse et al., 2001 (b)).

iii. Geophysical: Surface geophysical instruments are based on wave propagation and reflection measurements. A signal transmitted into the water is reflected back by interfaces between materials with different physical properties. The cost and complexity of the equipment and interpretation of the data are limiting factors for widespread use and application as a portable scour monitoring device.

Geophysical instrumentation is best used as a forensic tool, to evaluate scour conditions that existed during a previous flood. The primary limitation of geophysical equipment is the specialized training and cost involved in making this type of measurement (Lagasse et al., 2001 (b)).

A primary difference between sonar and geophysical techniques is that geophysical methods provide sub bottom, while sonar can only "see" the water-soil interface and is not able to penetrate the sediment layer (Lagasse et al., 2001 (b)).

4.4.1.2 Deploying the instrument(s)

Placing the instrument to the right place in the right style is an important and critical component in a successful monitoring. Generally, at flood periods, it is harder to make measurements than the normal flow regime. Therefore, deploying plays a great role in the procedure. There are two ways for placing the instruments; one is from the bridge deck and the other from water surface, i.e. from boats.

4.4.1.3 Positioning

When data have been collected, the positioning should be arranged in a way that the result could be located, especially relative to the structure. The most significant advancement for this positioning may be in the use of Global Positioning Systems (GPS). GPS is a positioning system based on a collection of satellites orbiting the earth (Lagasse et al., 2001 (b)). An advantage of GPS is that line-of-sight between control points is not necessary, i.e. GPS survey can be completed between points that do not see each other. Additionally, GPS works at night and during inclement weather, which could be a real advantage for scour monitoring during flood conditions. The most significant disadvantage of GPS is the inability to get a measurement in locations where overhead obstructions exist, such as tree canopy or bridge decks. However, GPS measurements up to the bridge face, without venturing under the bridge, have been successful.

4.4.1.4 Data Storage

In basic system, data could be stored in archived notebooks. However, with improved technology and increased amount of data, there are more systematic data storage methods. A few examples for these are hydrometeorological data loggers, laptop computers and more recently palm computers and organizers (Lagasse et al., 2001 (b)).

4.4.2 Fixed Instrumentation

They are the instrumentation that are installed once and used in certain frequencies for the inspection of the structure. Once they are fixed, the installation problems are omitted. In literature, fixed instrumentation is stated to be grouped into four:

Sounding rods, buried or driven rods, fathometers and other buried devices (Lagasse et al., 2001 (b)).

Fixed instrumentation is best used when ongoing monitoring is required, recognizing that the location of maximum scour may not always be where the instrument was originally installed.

The choice of the type of the instrument to be used is influenced by the characteristics of the site to apply. The geometry, structural, and hydraulic conditions dictate the necessities. All instruments tested are adaptable in some degree to vertical piers and abutments. Sloping piers and spill-through abutments present some problems. Driven rod instruments, such as the automated sliding collar or piezoelectric film device that are not fastened to the substructure can be used on sloping piers and abutments (Lagasse et al., 2001 (b)).

No single methodology or instrument can be utilized to solve the scour monitoring problems for all situations encountered in the field. Considering the wide range of operating conditions necessary, environmental hazards, such as debris and ice, and the variety of stream types and bridge geometries encountered in the field, it is obvious that several instrument systems using different approaches for detecting scour will be required (Lagasse et al., 2001 (b)).

The applications of these mentioned items that construct the hydraulic aspect of the inspection methodology are illustrated in the case studied in Chapter 6.

CHAPTER 5

THE PROPOSED INSPECTION ALGORITHM

Bridges are structures designed and constructed with great budget and labor. Therefore, it is essential to protect them in the best way both for the structure's health and in the aspect of economical considerations. The best and most suitable assessment algorithm for every country can be formed according to that country's political, economical, geographical and social conditions, needs, and resources.

In Turkey, KGM (General Directorate of Turkish Highways) has formed a visual inspection report; similar to which other countries had established. When this current system is analyzed and compared with some of the other current applications already mentioned before, it is observed that some modifications are needed and these would bring accuracy, easiness and increase the practicality of the inspection system. The current report of KGM is modified and a new proposal is established with some revisions and additional items that may yield more information.

The main goal of an inspection report must be its practicality. It has to be easy to operate and quick to understand. The easiness should be valid both for the in-situ examination and for the subsequent quantitative evaluation. The parameters in the inspection report should be clearly stated and the grading levels should be definite. The subjectivity should be hold in minimum and every indeterminate judgment should be supported with a suitable proof, such as pictures, sketches, etc.

When the current algorithm used in Turkey is interpreted, it can be realized that the system is lack of hydraulics point of view; especially when compared with structural aspect. It is a widely known fact that hydraulic perspective in river bridges is one of the most essential concerns to be dealt. It is stated that there are 5500 bridges in Turkey, of which many of them are defined as river bridges, facing hydraulic problems. Therefore, hydraulics point of view are included and emphasized more in the new proposal as many of the failures of river bridges in Turkey and throughout the world are known to occur because of hydraulic oriented problems.

In this inspection proposal, another revision is needed for the grading and evaluation system. Current Turkish practice uses four separate levels for grading with the degrees defined with letters. When letters are used, there is no sub-leveling which creates some indeterminist problems. If there are no sub-grades; the evaluation should be very discrete without any flexibility. Additionally the evaluation computation becomes harder as the grading is not numerical and there should be some quantitative values in order to reach for quantitative results. In this proposal, numerical values are suggested for grading. This numerical system creates a great comfort in the evaluation and interpretation of the parameters as they can easily be compared to each other.

The revised algorithm is derived from the current inspection system in Turkey, combined with other examples currently applied in other countries and some theoretical studies obtained from literature surveys. One of the major models is an inspection report currently used in Long Island, USA (PBQD, 2003). This is an extensive report; including a detailed inventory section, followed with the main inspection report and concluded with sketches, pictures and other details necessary for the bridge database. Although there is a couple of hydraulic and geotechnical elements, it is again focused on structural parameters. It uses a numerical grading system and overall results are obtained by taking the average of the values.

After the in-situ checklist is prepared, the next important step is the calculation and interpretation of these data. Collecting the data might be subjective. However, with the proper calculations and right interpretations, it should be compensated. The reliability and consistency of results are very important. There are a lot of parameters arranged in different sub-groups. However, their effects on the system are different according to their effect on the whole structure and the tendency of the element/material to fracture. Therefore, an importance ranking is established among the parameters and some coefficients are assigned to parameters according to their effect on the structure. This provides a weighted assessment.

The current Turkish visual inspection report has been adapted and a structural checklist shown in Table 5.1 is prepared. The underlined items are the ones that have been added to the checklist and do not exist within the original inspection algorithm (Table 2.2). These parameters are added to the checklist because their presence would provide additional information in the evaluation. With these items, grading is more significant and consistent within the parameters.

5.1 Structural Grading and Evaluation

Turkish practice on bridge inspection is based on the rating classified into four without any sub levels in between. However, in another bridge inspection report in Long Island, USA (PBQD, 2003); the scale is divided into seven parts, with four main levels, which are further supplemented with three sub-levels in order to prevent the hesitations of the inspector during grading. The four main levels divide the condition of any structure into four as failed, seriously deteriorated, minor deterioration and good condition. The sub levels are the situations that the structure cannot be placed into one of the major levels so that an intermediate situation seems appropriate. The followings are the detailed explanation of the grade levels:

Table 5.1 The Proposed Structural Checklist.

BRIDGE NAME					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks		**Metallic(M) /Elastomeric(E)**		Deformation	
Concrete Disintegration		Main Damage		Cracks	
Apparent Reinforcement		Support Bed		Concrete Disintegration	
Holes and cavities		Loss of elements (M)		Apparent Reinforcement	
Water leakage		Anchorage (M)		Holes and cavities	
OVERALL GRADE	**0.00**	Surface arrangement (E)		Water and debris abrasion	
BEAMS		Deformation (E)		Scour in foundation	
Steel (S) /Concrete(C)		**OVERALL GRADE**	**0.00**	**OVERALL GRADE**	**0.00**
Deformation		**PIERS**		**APPROACH FILL**	
Cracks		Deformation		Settlement and Slump	
Rusting (S)		Cracks		Erosion on road platform	
Bolts and Rivets (S)		Concrete Disintegration		Erosion in fill	
Welding (S)		Apparent Reinforcement		**OVERALL GRADE**	**0.00**
Concrete Disintegration (C)		Holes and cavities		**STABILIZATION**	
Apparent Reinforcement (C)		Water and debris abrasion		Settlement and Slump	
Holes and cavities (C)		Scour in foundation		Erosion	
OVERALL GRADE	**0.00**	**OVERALL GRADE**	**0.00**	Scour in bed level	
				OVERALL GRADE	**0.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving		**Border (B) /Railing(R)**		Noise	
Tire tracks		Cracks in the concrete (B)		Water leakage	
Cracks		Concrete Disintegration (B)		Deformation	
Holes and cavities		Apparent Reinforcement (B)		Holes and cavities	
OVERALL GRADE	**0.00**	Deformation in railing (R)		Loss of elements	
DRAINAGE		Rusting in railing (R)		*Loss of function*	
Pipe Damage		Deficiency in railing (R)		**OVERALL GRADE**	**0.00**
Blockage		**OVERALL GRADE**	**0.00**		
Cleanout					
OVERALL GRADE	**0.00**				

OTHER COMPONENT(S)	**0.00**

1: totally deteriorated, or in failed condition,

2: used to shade between ratings of 1 and 3,

3: serious deterioration or not functioning as originally designed,

4: used to shade between ratings of 3 and 5,

5: minor deterioration, but functioning as originally designed,

6: used to shade between ratings of 5 and 7,

7: new condition.

8: not applicable

9: unknown

The proposed algorithm herein is also based on this grading. As there are sublevels, it enlarges the inspectors' grading level. On the other hand, the grading level is not so wide; therefore, the subjectivity can be kept in small percentages. Personal error in judgment does not create large amounts of inaccuracy. The last two grades display the conditions more than a grade. The grade 8 (not applicable) means that the parameter cannot be evaluated as it does not exist or it is not valid for that structure, whereas the grade 9 (unknown) means that it is not possible to detect that parameter and to evaluate. The reason might be that it is not being visible or not possible to inspect, these two grades are essential for further inspection to see the previous situations and control the progress and/or regression.

After grading at the site, the average of every group is calculated by taking the average and assigned to that set as the overall group score. As mentioned before, these groups of parameters all affect the structure in different ways and with different aspects. Therefore, these groups are collected under three main sets. The elements of the structural evaluation are set into three main groups so that both the inspection and the evaluation could be easier and systematic: main body components, earth retaining components, and serviceability components. Each of them is evaluated with the sub-group elements and properties that are mentioned in the checklist. This grouping is done according to the function of the elements within the structure and concerning the similarities of the elements and their effects on the structure.

With the primary concern of how serious or sudden these components can affect the structure or how short the structure can survive without them, some constants (Table 5.2) are assigned to those in order to emphasize the importance of the one that are more significant than the others or vice versa. These coefficients are determined with the knowledge gathered with engineering experience in practical life and theoretical facts. The structural and earth retaining components are the main elements forming the structure and they determine the critical level of structural stability. Serviceability should also be considered with great care as they are the elements affecting the serviceability level of the structure. The problems occurring at serviceability components do not directly affect the stability of the structure. It influences the comfort in the usage and creates some safety problems from the point of users.

Table 5.2 The Coefficients Assigned to Structural Parameters.

Structural Weighted Coefficients	
Main Body Components	1.0
Earth Retaining Components	1.0
Serviceability Components	0.5

According to the grading level mentioned, a critical value is defined. This value, defined as five, designates if the overall condition is critical or not. It is the limit value that the structure functions but has deficiencies. The group and overall structure grades should be interpreted according to this limit value. However, whether these overall values are over or under the critical limits, sub element grades should also be checked separately and analyzed in order to beware of any problems occurring at any specific point. In order to see these, graphical representations are suggested in which the charts help to focus on those under the critical line. The ones that are drawn under the limit line should need some immediate monitoring, maintenance, and careful analysis. Due to the outcomes, the necessary precautions should be applied. Grouping into three gives an easiness to understand the problematic part of the structure. However, it is not enough to deeply realize the problem. In order to understand which element has a more emergent situation, the individual grading should be used in Table 5.1.

The charts drawn with the data obtained from the individual grading helps to show the differences in the identical elements of these twin type bridges. It provides a comparison between the new and old bridges and gives some ideas about the possible future condition of the new bridge. Furthermore, these charts help the observer to comprehend the results of the inspection easily, to see the relative and individual condition of every element.

When the grading and the graphical presentation do not help to convey the situation, photographs taken at the site and hand-drawn sketches can be used. During the inspection, photographing is a very important archiving method; both for reporting and for further studies and observations. In some critic cases, it can prevent the subjectivity of the inspector as the inspection group can discuss the condition with the help of the photographs taken. In the original inspection report, there should be a lot of pictures in order to state the condition of many elements. In this study, only the different parts or the more explanatory parts are used.

5.2 Hydraulic Grading and Evaluation

In literature, hydraulic assessment for the structural safety has not been studied extensively. Generally it is included as a part of the structural assessment or worked in a limited concept. However, as stated before, it is an extensive subject which must be handled separately.

Johnson et al. (1999) studied on the stabilization of river bed and established a checklist for the inspection of the conditions of river beds. They proposed a 13-item list composed of different parameters affecting the stabilization. They are selected as to be inspected visually, without any complex equipment or without any experimental analysis. As this method is clear enough and the determination of the parameters is easy and practical, it is added to the proposed inspection algorithm for Turkey.

In hydraulic assessment, the scale and the evaluation is completely different than the structural assessment. The assessment is based on the river stabilization condition. The elements are chosen according to that and evaluated separately, with the grade limits determined by each element's own conditional situation. The grading scale has been established and given in Table 5.3 in which H and V stand for the horizontal and vertical values of slope. According to the in-situ conditions, the necessary values are assigned to the relative parameters. In this case, the coefficients (Table 5.4), which are already determined in a previous study (Johnson et al., 1999), are directly multiplied with each parameter's grade and every parameter possesses a new weighted value. These weighted grades are summed up and the overall grade for the stabilization of the bed is obtained. Then, according the grade levels, given in Table 5.5, the condition is verbally specified.

The parameters in this river stabilization check are defined in the previous chapter. Most of them can be evaluated with visual observation. However, some may need a more experienced observer or the use of some basic measurement tools.

In this hydraulic checklist, the river bed is observed and the current condition is defined according to the scale in Table 5.5. If some problems are detected with this overall grade; then the evaluation table (Table 5.3) is analyzed and the one in the worst condition is given the priority for the maintenance and repair. The interval of 10-12, meaning "poor", is the most critical values to be worked on primarily.

Table 5.3 The Hydraulic Checklist Proposed by Johnson et al. (1999).

Item	Excellent (1-3)	Good (4-6)	Fair (7-9)	Poor (10-12)
Bank soil texture and coherence	Clay and silty clay, cohesive material	Clay loam to sandy clay loam	Sandy clay to sandy loam	loamy sand to sand; noncohesive material
Average bank slope	<3H:1V on both sides	<2H:1V, on one or both sides	<1.7H:1V one or both sides	>60° one or both sides
Vegetative bank protection	Wide band of woody vegetation	Medium band of woody vegetation	Small band of woody vegetation	less than 50% plant density and cover
Bank cutting	Little or none evident, raw banks<15cm	Some, raw banks<30 cm	Significant and frequent, raw banks:30-60 cm	Almost continuous cuts>60 cm
Mass wasting or bank failure	No or little evidence of potential mass wasting	evidence of infrequent and/or minor mass wasting	evidence of frequent/significant occurrences of mass wasting	frequent and extensive mass wasting
Bar development	Mature, narrow relative to stream width	Vegetation and/or with coarse gravel to cobbles	Bar width tends to be wide	Bar widths are generally greater than 1/2 the stream width at low flow
Debris jam potential	negligible	small amounts of debris present	Noticeable accumulation of all sizes	Moderate to heavy accumulations of various size debris present
Obstructions, flow deflectors and sediment traps	Rare or not present	Present	Moderately frequent and occasionally unstable obstructions	Frequent and often unstable causing a continual shift of sediment and flow
Channel bed material consolidation and armoring	Assorted sizes tightly packed, overlapping	Moderately packed with some overlapping	Loose assortment with no apparent overlap	Very loose assortment with no packing
τ_e	$\tau_e < 1$	$1 \leq \tau_e < 1.5$	$1.5 \leq \tau_e < 2.5$	$T_e \geq 2.5$
α (°)	$0 \leq \alpha \leq 5°$	$5 < \alpha \leq 10°$	$10 < \alpha \leq 30°$	$\alpha > 30°$
D_m (m)	D_m >35m	20< D_m <=35m	10< D_m <=20m	0< D_m <=10
M (%)	0-5	6-25	26-50	>50

Table 5.4 The Coefficients Assigned to Hydraulic Parameters (Johnson et al., 1999).

Hydraulic Weighted Coefficients	
Bank soil texture and coherence	0.6
Average bank slope	0.6
Vegetative bank protection	0.8
Bank cutting	0.4
Mass wasting or bank failure	0.8
Bar development	0.6
Debris jam potential	0.2
Obstructions, flow deflectors and sediment traps	0.2
Channel bed material consolidation and armoring	0.8
Shear stress ratio (τ_e)	1.0
High flow angle of approach to bridge (α)	0.8
Bridge distance from meander impact point (D_m)	0.8
Percentage of channel constriction (M)	0.8

For both structural and hydraulic checks, the inspection should be done with a very subjective manner. The situation should be observed well and if needed, necessary remarks, photographs, and/or sketches should be added to the report. After the evaluation, according to the overall score, if needed, subgroups should be studied and the priority of maintenance or repair is selected in relation to these values. In every inspection, even the overall grade is in the normal range, the sub-group scores should be checked in order to be alert for an unexpected problem embedded in other parameters.

Table 5.5 The Grading Scale of Hydraulic Parameters (Johnson et al., 1999).

GRADE	CONDITION
< 32	Excellent
32 - 54	Good
55 - 77	Fair
≥ 78	Poor

5.3 Reporting

The report for an inspection is a very essential part and should be worked on clearly in order to establish a practical and useful system. Reporting should not only be helpful during the site work but also for the future studies based on archiving. If the data storage is established in a well-organized system, then throughout time, it becomes easier to know about the present and/or previous condition of the structure. Reporting is also important because it is the tool to communicate with other engineers and inspectors about the structure. Therefore, it should not be complex and should be compatible with other systems.

The primary section of a reporting starts with the inventory part. This includes the name and type of the bridge, location, span length, pier properties, year of construction, river properties, inspection information, etc. These are the permanent data that can be filled either at site or at the office. It helps to differentiate the structure from other bridges and at the same time, it gives brief information for the structure that can be needed during the inspection or evaluation.

The second part is the inspection part, itself. It has the proposed checklists, both with structural and hydraulic points of view. It also includes the appropriate space for the inspector to add his/her comments, about these grading. These comments are generally in short expressions, mostly not complete sentences. The aim is to emphasize the important problems and areas to focus on. Additionally, there might be points to be mentioned that cannot be stated in the inspection checklist.

The third part is the sketching and photographing which is made up of a plan of the structure and very basic drawings from side and top view. At the site, inspector marks the critical regions on these drawings and comment on these areas at the appropriate spaces left on these pages. This helps the inspector to remember the problem when working on the structure and provides the other inspectors and office engineers to understand the problem more easily. When the sketches are not very comprehensive, photographs are taken to support the situation. They also function in order to prevent the objective judgment of the inspector.

An inspection report is established in this study and a sample inspection report is presented in Appendix A. With this example, the parts of the report, sketching and usage of visual aid are presented.

CHAPTER 6

CASE STUDIES

The importance and aim of this study is to create an inspection system and provide an application tool to Turkey in a practical manner. In the previous chapters, the description of various aspects to be considered in inspection studies has been introduced. In order to illustrate the application of the methodology defined in the previous chapter, some bridges around Ankara are chosen, inspected, and evaluated.

The selection criterion of these bridges is dependent on few parameters. The major condition is that they all are river bridges, such that at least one of the infrastructural elements is in contact with water. Another property that is common in many of these structures is that each has a twin bridge, just constructed adjacent to it. Typically, old one was constructed around 1950's, and the twin was constructed lately when the old bridge started to be insufficient to carry the traffic load. This creates an advantage of analyzing two structures on the same hydraulic and hydrologic conditions, comparing the differences due to their age and external factors. One more advantage can be stated as the old structure becomes an indication for the probable problems and deficiencies that would occur within the new bridge due to same hydrologic, hydraulic or external factors.

6.1 Esenboğa Bridges

The structure is located approximately 19 km from Ankara, on Ankara-Kastamonu state highway, passing over Çubuk Stream. Esenboğa Bridge is composed of two bridges; one is constructed in 1954 and renewed in 1979, whereas the second bridge, adjacent to the first one, is constructed in 2000. These two bridges have different structural designs. Two aforementioned bridges can be distinguished from each other by naming them as the "old bridge" and the "new bridge" which are the right and the left bridges, respectively, on the way to Ankara-Kastamonu. Both bridges have three-spans; namely, the old one having 5 girders per one span, whereas new one has 11 post tensioned beams. The abutments of the old bridge are of spill through type, whereas the new bridge has vertical wall abutments.

The in-situ inspection was applied on March 16th 2006, with the proposed checklist applications. The structural inspection is completed by grading the necessary items according to the checklist proposed (Tables 6.1 and 6.2) and taking necessary photographs which can be seen in Appendix B (Figure B.1- Figure B.12). During this inspection Schmidt hammer is used to measure the strength of concrete.

With the observations done at the site, the evaluation is conducted. The items that seem to work but with some problems are graded with five (5), whereas the ones that merely function but still exist are graded with three (3). The items that cannot be inspected due to lack of view or presence of water are rated as "unknown" and the ones that are not valid for that specific structure are marked as "not applicable". The overall grades for each component and the total weighted grade for the overall structure are shown in Table 6.3 for both bridges.

According to Table 6.3, the cumulative grades, 5.29 and 6.65, show that both structures, old and new respectively, do not need an immediate maintenance as both of their overall grade values pass the critical limit of five. However, when the components are analyzed separately, there appear problems. In the old bridge, the main body components have been graded as 4.77. Being below the critical value, the elements should be observed with a more detailed manner. The inspection sheet should be examined again to understand the source of the deficiency (Table 6.1). Among main body components, made up of four separate groups, the worst condition is observed to be within the deck, with the lowest grade of 4.00. When the sub-element grades are observed, it is seen that there is an excessive disintegration of concrete (Figure B.3 and B.4). The reinforcement is all become apparent (Figure B.5), losing the integrity of the entire concrete layer. Concrete patching or re-decking can be applied.

Table 6.1 Grading of the old Esenboğa Bridge.

ESENBOĞA BRIDGE (old)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	5	**Metallic(M) /Elastomeric(E)**	*	Deformation	5
Concrete Disintegration	3	Main Damage	8	Cracks	7
Apparent Reinforcement	4	Support Bed	8	Concrete Disintegration	5
Holes and cavities	9	Loss of elements (M)	8	Apparent Reinforcement	6
Water leakage	4	Anchorage (M)	8	Holes and cavities	5
OVERALL GRADE	**4.00**	Surface arrangement (E)	8	Water and debris abrasion	5
BEAMS		Deformation (E)	8	Scour in foundation	3
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**5.00**	**OVERALL GRADE**	**5.14**
Deformation	5	**PIERS**		**APPROACH FILL**	
Cracks	5	Deformation	5	Settlement and Slump	7
Rusting (S)	8	Cracks	6	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	4	Erosion in fill	7
Welding (S)	8	Apparent Reinforcement	7	**OVERALL GRADE**	**7.00**
Concrete Disintegration (C)	5	Holes and cavities	9	**STABILIZATION**	
Apparent Reinforcement (C)	6	Water and debris abrasion	5	Settlement and Slump	4
Holes and cavities (C)	9	Scour in foundation	5	Erosion	4
OVERALL GRADE	**5.25**	**OVERALL GRADE**	**5.33**	Scour in bed level	9
				OVERALL GRADE	**4.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	7	**Border (B) /Railing(R)**	R	Noise	7
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	3
Cracks	7	Concrete Disintegration (B)	8	Deformation	5
Holes and cavities	7	Apparent Reinforcement (B)	8	Holes and cavities	9
OVERALL GRADE	**7.00**	Deformation in railing (R)	5	Loss of elements	5
DRAINAGE		Rusting in railing (R)	6	Loss of function	5
Pipe Damage	7	Deficiency in railing (R)	6	**OVERALL GRADE**	**5.00**
Blockage	7	**OVERALL GRADE**	**5.67**		
Cleanout	7				
OVERALL GRADE	**7.00**				

* The supports cannot be counted as elastomeric or metallic. A material similar to styrofoam is used. The overall grade can be evaluated as 5.

The individual grades should also be checked for the items that are rated with grade three (3) or lower. Then, addition to the parameters mentioned before in the old bridge, scouring at the foundation and leakage at expansion joints are observed. If re-decking is considered, expansion joints can be eliminated by making the deck continuous at the piers.

Table 6.2 Grading of the new Esenboğa Bridge.

ESENBOĞA BRIDGE (new)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	7	**Metallic(M) /Elastomeric(E)**	E	Deformation	7
Concrete Disintegration	7	Main Damage	7	Cracks	7
Apparent Reinforcement	7	Support Bed	7	Concrete Disintegration	7
Holes and cavities	7	Loss of elements (M)	8	Apparent Reinforcement	7
Water leakage	7	Anchorage (M)	8	Holes and cavities	7
OVERALL GRADE	**7.00**	Surface arrangement (E)	7	Water and debris abrasion	5
BEAMS		Deformation (E)	7	Scour in foundation	7
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**7.00**	**OVERALL GRADE**	**6.71**
Deformation	7	**PIERS**		**APPROACH FILL**	
Cracks	7	Deformation	6	Settlement and Slump	7
Rusting (S)	8	Cracks	7	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	7	Erosion in fill	7
Welding (S)	8	Apparent Reinforcement	7	**OVERALL GRADE**	**7.00**
Concrete Disintegration (C)	7	Holes and cavities	7	**STABILIZATION**	
Apparent Reinforcement (C)	7	Water and debris abrasion	5	Settlement and Slump	6
Holes and cavities (C)	7	Scour in foundation	9	Erosion	4
OVERALL GRADE	**7.00**	**OVERALL GRADE**	**6.50**	Scour in bed level	9
				OVERALL GRADE	**5.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	7	**Border (B) /Railing(R)**	R	Noise	8
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	8
Cracks	7	Concrete Disintegration (B)	8	Deformation	8
Holes and cavities	7	Apparent Reinforcement (B)	8	Holes and cavities	8
OVERALL GRADE	**7.00**	Deformation in railing (R)	7	Loss of elements	8
DRAINAGE		Rusting in railing (R)	7	Loss of function	8
Pipe Damage	7	Deficiency in railing (R)	7	**OVERALL GRADE**	**0.00**
Blockage	7	**OVERALL GRADE**	**7.00**		
Cleanout	9				
OVERALL GRADE	**7.00**				

In order to see the problems in the elements separately and easily and to detect whether there are any critical situations, graphical representations are prepared as shown in Figure 6.1. With the help of this graphical representation, previously mentioned problems with the elements of the components can be perceived more easily. For instance, with the overall grade, the old bridge is stated as being within the range of safety. However, when individual ratings are observed from Figure 6.1, it is easier to differentiate the critical elements, such as decks, supports, or the stabilization. In these figures a line is drawn to clarify the critical limit.

Table 6.3 Final grades of Esenboğa Bridges.

COMPONENT	OLD BRIDGE	NEW BRIDGE
Main Body Components	4.90	6.88
Earth Retaining Components	5.38	6.24
Serviceability Components	6.17	7.00
Cummulative Grade	**5.34**	**6.65**

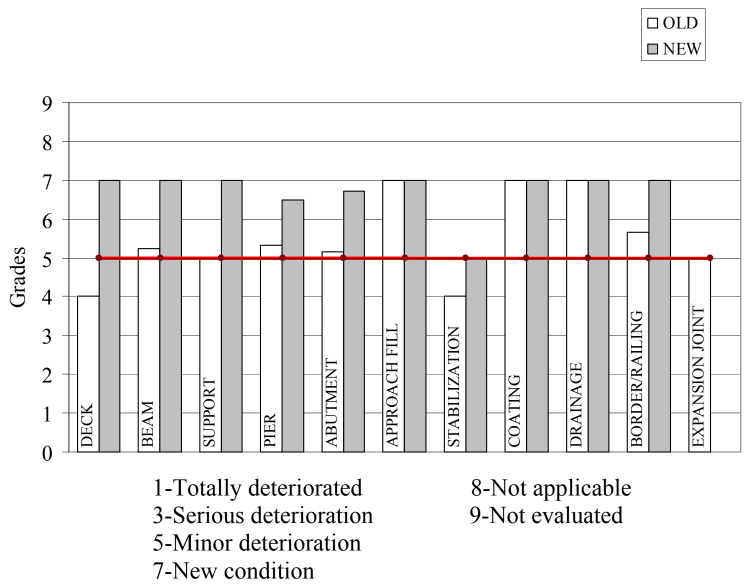


Figure 6.1 The Grades of the Elements Separately for Esenboğa Bridges.

The second part of the inspection is the stabilization of river bed. The aforementioned hydraulic checklist is applied for the river stability control and the necessary grading is also noted on the inspection list seen in Table 6.4. In this study, the related data are supported by a recent study carried out in the same site and necessary revisions are made, which had occurred due to time and hydraulic changes (Özdemir, 2003).

From the hydraulic point of view, the calculations are done and tabulated in Table 6.4 which gives the grades assigned to each stability indicator and the corresponding weighted grade. The overall grade is calculated as 50.4, which corresponds to the interval of "32-54", i.e. in good condition (Table 5.5). This indicates that there is no serious problem concerning the river stability. However, as the score is close to the upper bound of this interval, the structure should be checked regularly with respect to hydraulic and/or hydrologic oriented deficiencies. This check should give priority to the parameters that have the high grades during this inspection.

For Esenboğa Bridge, when the river stabilization grading is analyzed, it is clear to see that the most critical items are material consolidation and armoring within the river bed and the shear stress formed. This is not only understood from the quantitative values in Table 6.4 but also from the photographs taken at the site (Figure B.8 to B.12). This shows that the primary care should be given to the bed material consolidation in order to decrease the risk of failure.

Table 6.4 Hydraulic Grading and Evaluation of Esenboğa Bridges.

Parameter	Grade	Weighted Coefficient	Weighted grade
Bank soil texture and coherence	4	0.6	2.4
Average bank slope angle	2	0.6	1.2
Vegetative bank protection	6	0.8	4.8
Bank cutting	6	0.4	2.4
Mass wasting or bank failure	6	0.8	4.8
Bar development	3	0.6	1.8
Debris jam potential	8	0.2	1.6
Obstructions, flow deflectors and sediment traps	9	0.2	1.8
Channel bed material consolidation and armoring	10	0.8	8
Shear stress ratio	12	1	12
High flow angle of approach to bridge or culvert	6	0.8	4.8
Bridge or culvert distance from meander impact point	2	0.8	1.6
Percentage of channel constriction	4	0.8	3.2
		SUM	50.4

6.2 Kızılırmak Arch Bridge

This bridge, constructed in 1952, is located approximately 68 km away from Ankara, on Ankara-Kırıkkale State Highway. It passes over the Kızılırmak River with a span of 72 m. The deck is placed on a wide arch concrete beam which is supported by reinforced concrete beams and columns (Figure B.13).

The bridge does not have any piers as it is placed on the wide concrete arch and the supports are anchored to the ground. During the inspection on May, 14th 2006, the structure has no contact with the water due to low flow conditions. However, during high seasons, there is the probability of the support contacting the river. The inspection is conducted in the site and the grading is noted on the checklist. The related photographs taken at the site are put in Appendix B (Figure B.13 to B.20). The structural grades are tabulated in Table 6.5 and the results of the necessary calculations in the grouped system are given in Table 6.6.

According to the cumulative value, 4.70, the structure should be directly taken under a detailed inspection and the necessary precautions should be handled immediately. In order to determine the priority of the elements in need of maintenance, grades of the elements are analyzed and compared with each other.

Primarily, the components are observed and earth retaining components (abutments and approach fill) are observed to be in good condition, especially relative to the others. The rest of the components are observed to be problematic. This conclusion can also be derived easily from Figure 6.2.

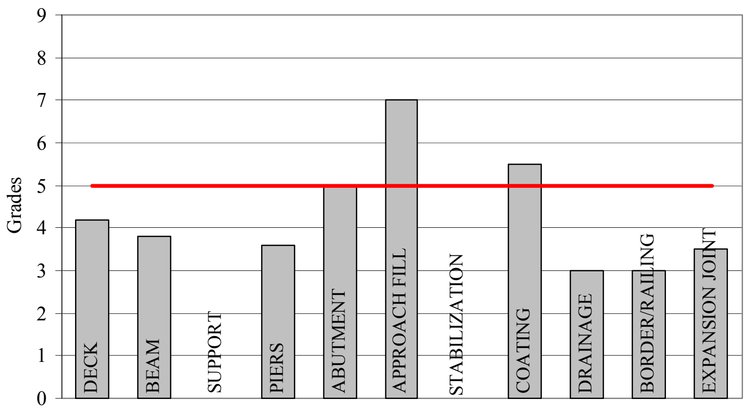
Table 6.5 Grading of Kızılırmak Arch Bridge.

KIZILIRMAK ARCH BRIDGE					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	4	**Metallic(M) /Elastomeric(E)**	non	Deformation	5
Concrete Disintegration	4	Main Damage	8	Cracks	6
Apparent Reinforcement	4	Support Bed	8	Concrete Disintegration	5
Holes and cavities	5	Loss of elements (M)	8	Apparent Reinforcement	3
Water leakage	4	Anchorage (M)	8	Holes and cavities	6
OVERALL GRADE	**4.20**	Surface arrangement (E)	8	Water and debris abrasion	8
BEAMS		Deformation (E)	8	Scour in foundation	8
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**0.00**	**OVERALL GRADE**	**5.00**
Deformation	4	**PIERS**		**APPROACH FILL**	**7.00**
Cracks	4	Deformation	4	Settlement and Slump	7
Rusting (S)	8	Cracks	4	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	3	Erosion in fill	7
Welding (S)	8	Apparent Reinforcement	3	**OVERALL GRADE**	**7.00**
Concrete Disintegration (C)	3	Holes and cavities	4	**STABILIZATION**	
Apparent Reinforcement (C)	2	Water and debris abrasion	8	Settlement and Slump	9
Holes and cavities (C)	6	Scour in foundation	8	Erosion	9
OVERALL GRADE	**3.80**	**OVERALL GRADE**	**3.60**	Scour in bed level	9
				OVERALL GRADE	**0.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	5	**Border (B) /Railing(R)**	R	Noise	4
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	4
Cracks	4	Concrete Disintegration (B)	8	Deformation	3
Holes and cavities	6	Apparent Reinforcement (B)	8	Holes and cavities	3
OVERALL GRADE	**5.50**	Deformation in railing (R)	3	Loss of elements	3
DRAINAGE		Rusting in railing (R)	3	Loss of function	4
Pipe Damage	9	Deficiency in railing (R)	3	**OVERALL GRADE**	**3.50**
Blockage	3	**OVERALL GRADE**	**3.00**		
Cleanout	3				
OVERALL GRADE	**3.00**				

Table 6.6 Final grades of Kızılırmak Arch Bridge.

COMPONENT	GRADE
Main Body Components	3.87
Earth Retaining Components	6.00
Serviceability Components	3.75
Cummulative Grade	**4.70**



1-Totally deteriorated
3-Serious deterioration
5-Minor deterioration
7-New condition
8-Not applicable
9-Not evaluated

Figure 6.2 The Grades of the Elements Separately for Kızılırmak Arch Bridge.

As seen from Figure 6.2, many of the elements are under the critical value. Therefore, there cannot be one major element to focus on primarily. The structure needs an extensive analysis and the necessary repair and maintenance should then be discussed within the context of practicality and economy. Cost estimation should be done for the maintenance of the deteriorated elements and for the replacement and reconstruction of the structure. The comparison of these two cases helps to decide the following step to do. If replacement is a more feasible option then repair, the structure may be considered to be re-constructed. This can be only determined with the appropriate tests and advanced analysis by professional bridge engineers.

The river stability is also observed as the second part of the inspection. The chart is filled by the observations at the site and with the quantitative values, the overall record is obtained as 17.6; seen in Table 6.7.

Table 6.7 Hydraulic Grading and Evaluation of Kızılırmak Arch Bridge.

Parameter	Grade	Weighted Coefficient	Weighted grade
Bank soil texture and coherence	9	0.6	5.4
Average bank slope angle	5	0.6	3
Vegetative bank protection	1	0.8	0.8
Bank cutting	1	0.4	0.4
Mass wasting or bank failure	2	0.8	1.6
Bar development	1	0.6	0.6
Debris jam potential	2	0.2	0.4
Obstructions, flow deflectors and sediment traps	1	0.2	0.2
Channel bed material consolidation and armoring	1	0.8	0.8
Shear stress ratio	2	1	2
High flow angle of approach to bridge or culvert	1	0.8	0.8
Bridge or culvert distance from meander impact point	1	0.8	0.8
Percentage of channel constriction	1	0.8	0.8
		SUM	17.6

The grade of the stability check for this stream is very low. This means there is no danger of a probable failure due to hydraulic aspect. Even from visual evaluation, the bridge seems to have no problem with the river stabilization; because the structure does not stand in the river in low seasons. Therefore, obtaining such a low value is not very surprising for this case. In normal seasons, the water flows in its own bed, without having any contact with the structure, the bank is well planted and the flow is almost one-dimensional, without any disturbing effects in close vicinity to the structure.

Taken as a whole, Kızılırmak Arch Bridge has no problem from hydraulic point of view. However, it needs an immediate maintenance from structural point of view.

The safety during the usage should quickly be provided. From structural aspect, the elements are all in serious damage and do not function properly.

6.3 Kızılırmak Bridges

They are two adjacent bridges, similar to Esenboğa bridges, one is constructed after some time when the old bridge has started to be overloaded and exceeded its capacity. They are constructed approximately 62 km from Ankara on Kırıkkale Highway, The old one is constructed in 1982, whereas the new bridge is very brand one. The total span of the structure is 126.70 m.

The old Kızılırmak Bridge, which is on the right when headed to Ankara, passes the span with 6 sets of circular piers of which three of them are currently in the water and the rest stand on the ground with the apparent excessive scouring at the foundations. Each span is made up of 4 reinforced concrete beams having lateral stiffener beams in between. The abutments are designed to be earth fill; however, even from the current appearance, it is obvious to understand that there occur some stability problems.

The new Kızılırmak Bridge has been constructed with post-tensioning beams. It passes the same span with 5 cylindrical pier sets. The location of the bridge is very close to the nearest meander (Figure B.29). Therefore, the river does not have enough time to convert its direction and become perpendicular to the structure. Hence the flow approaches to the structure with an angle. This may cause scouring problems at the piers of the bridge. Hence, it may be solved by constructing upstream spurs and improving the orientation of the guiding wall. Details of such application can be found in Yanmaz (2002).

The new Kızılırmak Bridge is composed of 11 pre-cast beams for each span. As the density of these beams is enough for the load carrying system, no stiffener is needed to be used in between them.

The inspection is performed to both bridges, on May 14th 2006, using the proposed check list and the in-situ grades are tabulated in Tables 6.8 and 6.9. In table 6.10, the final grading for the components and the structure in the overall condition are given. The photographs taken for visual aid are in Appendix B (Figure B.21 to B.30).

Table 6.8 Grading of Kızılırmak Old Bridge.

KIZILIRMAK BRIDGE (old)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	6	**Metallic(M) /Elastomeric(E)**	non	Deformation	5
Concrete Disintegration	6	Main Damage	8	Cracks	6
Apparent Reinforcement	6	Support Bed	8	Concrete Disintegration	5
Holes and cavities	6	Loss of elements (M)	8	Apparent Reinforcement	6
Water leakage	5	Anchorage (M)	8	Holes and cavities	5
OVERALL GRADE	**5.80**	Surface arrangement (E)	8	Water and debris abrasion	8
BEAMS		Deformation (E)	8	Scour in foundation	8
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**0.00**	**OVERALL GRADE**	**5.40**
Deformation	7	**PIERS**		**APPROACH FILL**	
Cracks	6	Deformation	3	Settlement and Slump	3
Rusting (S)	8	Cracks	5	Erosion on road platform	6
Bolts and Rivets (S)	8	Concrete Disintegration	6	Erosion in fill	3
Welding (S)	8	Apparent Reinforcement	6	**OVERALL GRADE**	**4.00**
Concrete Disintegration (C)	6	Holes and cavities	6	**STABILIZATION**	
Apparent Reinforcement (C)	5	Water and debris abrasion	2	Settlement and Slump	3
Holes and cavities (C)	6	Scour in foundation	2	Erosion	3
OVERALL GRADE	**6.00**	**OVERALL GRADE**	**4.29**	Scour in bed level	1
				OVERALL GRADE	**2.33**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	3	**Border (B) /Railing(R)**	R	Noise	7
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	6
Cracks	5	Concrete Disintegration (B)	8	Deformation	5
Holes and cavities	5	Apparent Reinforcement (B)	8	Holes and cavities	7
OVERALL GRADE	**5.00**	Deformation in railing (R)	6	Loss of elements	6
DRAINAGE		Rusting in railing (R)	5	Loss of function	6
Pipe Damage	6	Deficiency in railing (R)	6	**OVERALL GRADE**	**6.17**
Blockage	7	**OVERALL GRADE**	**5.67**		
Cleanout	7				
OVERALL GRADE	**6.67**				

Table 6.9 Grading of Kızılırmak New Bridge.

KIZILIRMAK BRIDGE (new)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	7	**Metallic(M) /Elastomeric(E)**	E	Deformation	6
Concrete Disintegration	7	Main Damage	7	Cracks	7
Apparent Reinforcement	7	Support Bed	7	Concrete Disintegration	6
Holes and cavities	7	Loss of elements (M)	8	Apparent Reinforcement	7
Water leakage	5	Anchorage (M)	8	Holes and cavities	7
OVERALL GRADE	**6.60**	Surface arrangement (E)	7	Water and debris abrasion	8
BEAMS		Deformation (E)	7	Scour in foundation	8
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**7.00**	**OVERALL GRADE**	**6.60**
Deformation	7	**PIERS**		**APPROACH FILL**	
Cracks	7	Deformation	6	Settlement and Slump	7
Rusting (S)	8	Cracks	7	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	5	Erosion in fill	5
Welding (S)	8	Apparent Reinforcement	6	**OVERALL GRADE**	**6.33**
Concrete Disintegration (C)	7	Holes and cavities	7	**STABILIZATION**	
Apparent Reinforcement (C)	7	Water and debris abrasion	6	Settlement and Slump	7
Holes and cavities (C)	7	Scour in foundation	6	Erosion	7
OVERALL GRADE	**7.00**	**OVERALL GRADE**	**6.14**	Scour in bed level	7
				OVERALL GRADE	**7.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	7	**Border (B) /Railing(R)**	R	Noise	6
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	7
Cracks	7	Concrete Disintegration (B)	8	Deformation	6
Holes and cavities	7	Apparent Reinforcement (B)	8	Holes and cavities	5
OVERALL GRADE	**7.00**	Deformation in railing (R)	7	Loss of elements	7
DRAINAGE		Rusting in railing (R)	7	Loss of function	4
Pipe Damage	9	Deficiency in railing (R)	7	**OVERALL GRADE**	**5.83**
Blockage	2	**OVERALL GRADE**	**7.00**		
Cleanout	9				
OVERALL GRADE	**2.00**				

From these results, tabulated in Table 6.10, it is observed that the old bridge is under the critical limits with an overall grade of 4.88. When three major components are analyzed separately, it is clearly seen that the main problem affecting the whole structural evaluation is the earth retaining components. The other two components (main body and serviceability) do not need an emergency maintenance, relative to earth retaining components. However, primarily piers, then approach fill and stabilization elements should be monitored immediately. When the individual grades are observed, it is very clear that there is a serious scouring problem around the piers, causing deformation at the elements. Reinforced earth is a method to rehabilitate abutments in bad conditions due to erosion. Also the approach fill does not function well as disintegrated parts are observed (Figure B.21 and B.22).

Table 6.10 Final grades of Kızılırmak Bridges.

COMPONENT	OLD BRIDGE	NEW BRIDGE
Main Body Components	5.36	6.69
Earth Retaining Components	3.91	6.64
Serviceability Components	5.88	5.46
Cummulative Grade	**4.88**	**6.42**

The new bridge has no serious problems. The only point to be mentioned is the serviceability condition as it has the lowest grade. As a brand new bridge, that value is under the expected condition. If the assessments at this young bridge show a value of 5.46, then the engineer should pay attention and a detailed investigation might be done among the parameters. Figure 6.3 shows the detailed assessments. It is clearly seen from this figure that drainage elements are below the red line; hence they create a great problem within the structure. A quick investigation should be carried out and the blockage problem that is observed in Table 6.9 can be terminated.

The hydraulic stabilization inspection is also conducted and presented in Table 6.11. From this table, the result can be observed as 43.6, which is in the interval of 32-55, corresponding to “good”. Even though the value is definitely within the interval of “good”, the separate parameters should be briefly checked. The highest grade is given to the approach angle of the river. Even with this highest grade, no problem seems to occur within the river stabilization.

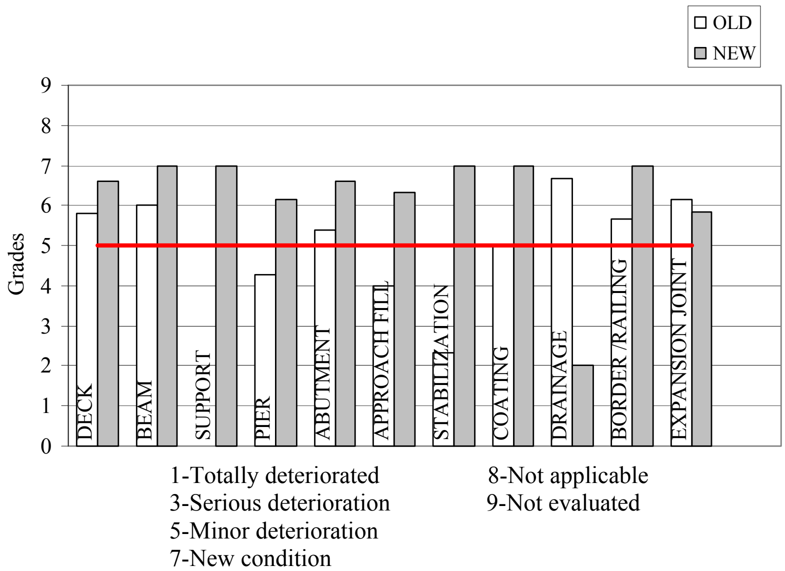


Figure 6.3 The Grades of the Elements Separately for Kızılırmak Bridges.

Table 6.11 Hydraulic Grading and Evaluation of Kızılırmak Bridges.

Parameter	Grade	Weighted Coefficient	Weighted grade
Bank soil texture and coherence	3	0.6	1.8
Average bank slope angle	3	0.6	1.8
Vegetative bank protection	8	0.8	6.4
Bank cutting	3	0.4	1.2
Mass wasting or bank failure	6	0.8	4.8
Bar development	3	0.6	1.8
Debris jam potential	3	0.2	0.6
Obstructions, flow deflectors and sediment traps	3	0.2	0.6
Channel bed material consolidation and armoring	6	0.8	4.8
Shear stress ratio	7	1	7
High flow angle of approach to bridge or culvert	9	0.8	7.2
Bridge or culvert distance from meander impact point	4	0.8	3.2
Percentage of channel constriction	3	0.8	2.4
		SUM	43.6

Taken as a whole, Kızılırmak Bridges do not need an urgent maintenance both in structural and hydraulic point of view. However; some elements should be analyzed with a greater care and essential actions should be applied. Although the overall grades for both structures are over the limits, it is better to provide the individual repair if any element needs.

6.4 Özçay (Kargılı) Bridges

Özçay Bridges are another twin bridges on Ankara-Kırıkkale Highway, approximately 60 km away from Ankara. The right lane when heading to Ankara is the new bridge, constructed in 1976. On the other hand the old one is constructed in 1951. The span of these bridges is relatively smaller than the other examined bridges as it passes only 25 m.

The old bridge passes the span with two openings, having one pier, located just in the middle. The spans are designed with four reinforced concrete beams. However, the new bridge is designed with 11 post-tensioned pre-cast concrete beams. Due to this strong structural design, no piers are needed. The new bridge has vertical wall abutments, whereas the old one's abutments are spill through.

With the observation performed at site on May 14^{th} 2006, the necessary remarks are gathered (Tables 6.12 and 6.13). Results for both bridges are evaluated after the in-situ inspection, as seen in Table 6.14. It is clear to see that both bridges are in good condition when the overall grades are concerned, which are 6.35 and 6.61, for the old and new bridges, respectively. However, it is always necessary to check the separate components' grades and individual parameters.

With these bridges, there seems no problem even with the separate components' grade. Only the serviceability component of the old bridge attracts attention as it has the lowest grade among the others. It is also close to the critical limit. Therefore, elements within this component should be observed to find the source of the problem. When the grading sheet is analyzed (Table 6.12), it is seen that the individual condition of expansion joints is not as functional as the overall structure (Figure B.32). The joints are seemed to lose some of their elements and hence their functions; probably due to excessive use and some internal problems; such as water leakage. The necessary action to do is to rehabilitate the elements, strengthening the concrete, using fiber sheets or replace some parts completely if possible. It should be applied carefully, without damaging the structure during this maintenance. The photographs taken at the site are also useful sources to understand the condition of the elements (Figure B.31 to B.38).

Table 6.12 Grading at Özçay (Kargılı) Old Bridge.

ÖZÇAY (KARGILI) BRIDGE (old)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	6	**Metallic(M) /Elastomeric(E)**	non	Deformation	7
Concrete Disintegration	6	Main Damage	8	Cracks	7
Apparent Reinforcement	6	Support Bed	8	Concrete Disintegration	7
Holes and cavities	6	Loss of elements (M)	8	Apparent Reinforcement	7
Water leakage	6	Anchorage (M)	8	Holes and cavities	7
OVERALL GRADE	**6.00**	Surface arrangement (E)	8	Water and debris abrasion	8
BEAMS		Deformation (E)	8	Scour in foundation	8
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**0.00**	**OVERALL GRADE**	**7.00**
Deformation	7	**PIERS**		**APPROACH FILL**	
Cracks	6	Deformation	7	Settlement and Slump	7
Rusting (S)	8	Cracks	6	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	6	Erosion in fill	6
Welding (S)	8	Apparent Reinforcement	7	**OVERALL GRADE**	**6.67**
Concrete Disintegration (C)	5	Holes and cavities	6	**STABILIZATION**	
Apparent Reinforcement (C)	7	Water and debris abrasion	6	Settlement and Slump	7
Holes and cavities (C)	7	Scour in foundation	7	Erosion	7
OVERALL GRADE	**6.40**	**OVERALL GRADE**	**6.43**	Scour in bed level	7
				OVERALL GRADE	**7.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**	**6.00**	**EXPANSION JOINT**	**4.80**
Waving	6	**Border (B) /Railing(R)**	R	Noise	9
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	4
Cracks	5	Concrete Disintegration (B)	8	Deformation	4
Holes and cavities	4	Apparent Reinforcement (B)	8	Holes and cavities	6
OVERALL GRADE	**5.50**	Deformation in railing (R)	6	Loss of elements	5
DRAINAGE		Rusting in railing (R)	7	Loss of function	5
Pipe Damage	9	Deficiency in railing (R)	5	**OVERALL GRADE**	**4.80**
Blockage	9	**OVERALL GRADE**	**6.00**		
Cleanout	9				
OVERALL GRADE	**0.00**				

Table 6.13 Grading of Özçay (Kargılı) New Bridge.

ÖZÇAY (KARGILI) BRIDGE (new)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	7	**Metallic(M) /Elastomeric(E)**	E	Deformation	7
Concrete Disintegration	7	Main Damage	7	Cracks	7
Apparent Reinforcement	7	Support Bed	7	Concrete Disintegration	7
Holes and cavities	7	Loss of elements (M)	8	Apparent Reinforcement	7
Water leakage	7	Anchorage (M)	8	Holes and cavities	7
OVERALL GRADE	**7.00**	Surface arrangement (E)	7	Water and debris abrasion	8
BEAMS		Deformation (E)	7	Scour in foundation	8
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**7.00**	**OVERALL GRADE**	**7.00**
Deformation	7	**PIERS**		**APPROACH FILL**	
Cracks	7	Deformation	8	Settlement and Slump	4
Rusting (S)	8	Cracks	8	Erosion on road platform	5
Bolts and Rivets (S)	8	Concrete Disintegration	8	Erosion in fill	4
Welding (S)	8	Apparent Reinforcement	8	**OVERALL GRADE**	**4.33**
Concrete Disintegration (C)	7	Holes and cavities	8	**STABILIZATION**	
Apparent Reinforcement (C)	7	Water and debris abrasion	8	Settlement and Slump	7
Holes and cavities (C)	7	Scour in foundation	8	Erosion	7
OVERALL GRADE	**7.00**	**OVERALL GRADE**	**0.00**	Scour in bed level	7
				OVERALL GRADE	**7.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	7	**Border (B) /Railing(R)**	R	Noise	6
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	6
Cracks	7	Concrete Disintegration (B)	8	Deformation	7
Holes and cavities	7	Apparent Reinforcement (B)	8	Holes and cavities	7
OVERALL GRADE	**7.00**	Deformation in railing (R)	7	Loss of elements	7
DRAINAGE		Rusting in railing (R)	7	Loss of function	5
Pipe Damage	7	Deficiency in railing (R)	7	**OVERALL GRADE**	**6.33**
Blockage	7	**OVERALL GRADE**	**7.00**		
Cleanout	7				
OVERALL GRADE	**7.00**				

Table 6.14 Final grades of Özçay (Kargılı) Bridges.

COMPONENT	OLD BRIDGE	NEW BRIDGE
Main Body Components	6.28	7.00
Earth Retaining Components	6.89	6.11
Serviceability Components	5.43	6.83
Cummulative Grade	**6.35**	**6.61**

From the tables, the new bridge is determined as a non-problematic structure. However, when Figure 6.4 is examined, the bad condition at the approach fill of the bridge is realized. Then, Table 6.13 is re-analyzed and it is seen that there occurs problems with the stability of the approach fill as there are settlements and slumps; with erosions (Figure B.35). In this case, the embankment should be braced.

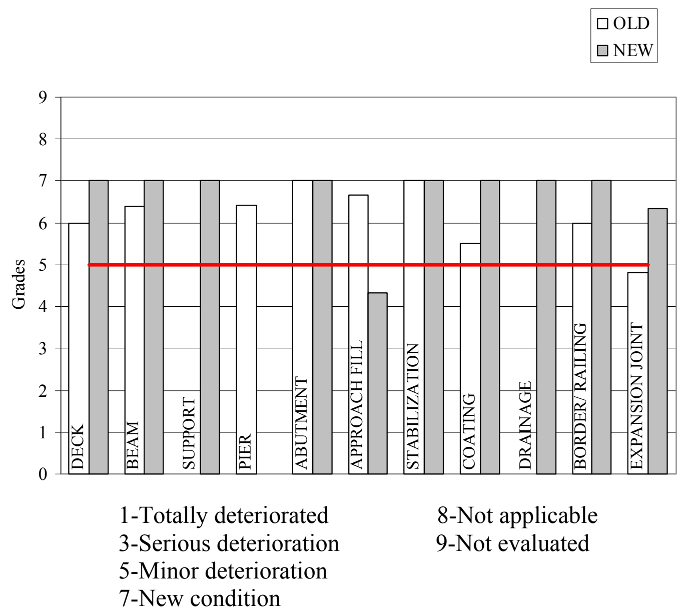


Figure 6.4 The Grades of the Elements Separately for Özçay (Kargılı) Bridges.

Then, the second part of the inspection is conducted. The river stabilization observation is carried out and the grades are displayed in Table 6.15. It shows that the evaluation is found out to be 62.4. According to the grading scale chart for the results (Table 5.5), the stabilization condition for Kargılı Bridge can be stated as "fair", being in the region of 55-78. This result means that the structure needs maintenance for its stabilization. It is not completely in a failure situation but an urgent analysis should be applied. The river bed should be monitored and the priority of the parameters to be monitored is chosen from Table 6.13. It is seen that there are four parameters that are evaluated as "poor" which is in the interval of 10-12. These are bank protection, bar development, debris accumulation, and shear stress ratio. These four separate parameters presenting the deficiencies in their own properties mean the river bed needs urgent rehabilitation. The stability of the river bed is very important as the whole system is based on it. Therefore, any detected problem like in Kargılı Bridge should be handled immediately.

Table 6.15 Hydraulic Grading and Evaluation of Özçay (Kargılı) Bridges.

Parameter	Grade	Weighted Coefficient	Weighted grade
Bank soil texture and coherence	9	0.6	5.4
Average bank slope angle	2	0.6	1.2
Vegetative bank protection	10	0.8	8
Bank cutting	3	0.4	1.2
Mass wasting or bank failure	7	0.8	5.6
Bar development	11	0.6	6.6
Debris jam potential	10	0.2	2
Obstructions, flow deflectors and sediment traps	2	0.2	0.4
Channel bed material consolidation and armoring	9	0.8	7.2
Shear stress ratio	12	1	12
High flow angle of approach to bridge or culvert	5	0.8	4
Bridge or culvert distance from meander impact point	8	0.8	6.4
Percentage of channel constriction	3	0.8	2.4
		SUM	62.4

Özçay (Kargılı) Bridge is a short span river bridge. As the depth of the water is not so deep in the vicinity of the bridge, the structure is not directly affected. However, the flow is active and effective on the river bed as it creates a very damaged situation at the bed.

6.5 Results and Discussion

With the inspection trips to several bridges around Ankara, the current condition of these bridges are assessed during the study. The interpretation should be done according to two parameters. The first parameter is the old data obtained in previous inspections. They show the change of the condition, both in positive and negative aspects. As there is always the date of inspection, the acceleration in the change can also be detected and this helps to assume the prospective problems. Second parameter to be analyzed is the condition of the bridge relative to the others. The primary aim of this inspection method is not giving qualitative values to each bridge but to rank the bridges, especially on the same highway, according to their damage risks. Therefore, not only the grade itself is meaningful but the ranking is important.

These two comparative evaluations (one with its previous condition, one with other structures) are both very important and deterministic in the final results of the inspection. The algorithm in this study is applied with the evaluation and condition assessment steps. Unfortunately, there are no data obtained previously and periodically because of the lack of budget and personnel. Therefore, throughout this study only the present data are used. Although the direct results are tabulated in the related sections, the comparative ones are summarized in Table 6.16.

Table 6.16 Summary of structural grades of all the bridges.

BRIDGE	Main Body Components	Earth Retaining Components	Serviceability Components	Cummulative
Esenboğa old	**4.77**	5.38	6.17	**5.29**
Esenboğa new	6.88	6.24	7.00	**6.65**
Kızılırmak arch	**3.87**	6.00	**3.75**	**4.70**
Kızılırmak old	5.36	**3.91**	5.88	**4.88**
Kızılırmak new	6.69	6.64	5.46	**6.42**
Özçay old	6.28	6.89	5.43	**6.35**
Özçay new	7.00	6.11	6.83	**6.61**

These grades that are evaluated with visual inspection and derived with necessary calculations cannot be taken as the quantitative evaluation grades of the structure. They are values that are used to qualify the structure relative to each other and to its previous condition and guide the engineer to decide on the priority of the maintenance requirement of the structure.

Grouping the elements within the structures into three in structural evaluation also helps the authorities to find out where the problem is and to choose the right area/section to focus on for the maintenance. This causes to gain time, money and man labor.

From Table 6.16, the following results are obtained:

- Among overall grades, Kızılırmak Arch Bridge and old Kızılırmak Bridge are the ones whose results lie under the critical limit which is determined as 5. When these two structures are examined with the grades that each component has, Kızılırmak Arch Bridge's situation is more serious than old Kızılırmak Bridge, because two of the groups of Kızılırmak Arch Bridge fall under the limit. On the other hand, old Kızılırmak Bridge has only one value lower than the limit. Therefore, the priority in this case should be on the arch bridge. However, the old bridge should also be monitored with detailed inspection and necessary repair should be applied urgently.

- Old Esenboğa Bridge has been evaluated as 5.29 which is over the critical limit. If the structures are evaluated only with their cumulative records, then this bridge should be classified as a non-problematic bridge. However, when an individual component grade is concerned, there is one component under the critical limit. Therefore, that element with low grade should be monitored and the necessary repair and strengthening actions as mentioned in the related section, should be taken as early as possible.

- Among these seven bridges, only two of them are evaluated as critical if the overall grading is concerned. When the components' individual grades are concerned, one other bridge is detected as critical (Old Esenboğa Bridge). This does not mean the other "safe" structures are practically safe. The other structures should also be inspected carefully and the problematic regions should be determined and archived. In the subsequent inspection, the progression of the problem can be observed and if it is getting worse, then the necessary action should be done.

- According to Table 6.16, some results and interpretations are accessed about the bridges. However, sometimes, this evaluation and tabulation might cause to miss some small but important failures of elements. Therefore, during the inspection, the technician (engineer or other related person) should photograph the deficiency or the problematic areas in order to use as documentation for the structure. Figures and sketches are the aiding tools in these cases. Photographs taken during this study are placed in Appendix B.

- During the analysis of the cases, it is observed that there is the possibility of comparing the condition of the twin bridges. They are located on the same river with the same hydraulic and hydrologic conditions. However, there is a difference between the values obtained from them. One of the reasons is the time affect on the structure. These twin bridges have approximately 30 years between their dates of construction. One other reason for the grade difference is the technology they are built with. Mostly, twin bridges have different structural formation. On the other hand, observation on twin bridges may also give some idea for the future condition of the new one, looking at the old one's current state.

CHAPTER 7

DISCUSSIONS AND CONCLUSIONS

7.1 Concluding Discussion on Bridge Inspection

River bridges are subject to various external and internal effects some of which cannot be accounted during the design because of uncertainties. There is always a certain risk of damage or failure and that risk cannot be completely omitted but it can be reduced with the proper inspection study which is followed by the appropriate actions applied to that condition. Periodic maintenance and repair intend to decrease the number of failures or lessen the serviceability problems that might happen due to deficiencies which may originate from structural, geotechnical, hydraulic, and materials aspects. In other words, inspection and related maintenance reduces the existing risk.

Inspection of a structure is a qualitative assessment of all the elements constituting the structure together. However, every element should be assessed in a way that an overall result can be derived from these separate assessments. This means there should be a compatible evaluation scale, thus a quantitative identification method is derived. The quantitative assessment should be followed with the appropriate interpretations and suggestions according to the results obtained. According to the situations obtained with the inspection, different options become valid. Basically they can be classified into two as repair or renewal. Typically cost estimation is the best method to decide between these two options. If bridge is in very poor condition, the repair of many elements might be more expensive than reconstructing it. However, if a periodic inspection is applied systematically, than the structure’s condition would be known far before it becomes so damaged. Then the repair would be easier and cost less. Renewal of the system is generally a more complex and relatively extensive task. Not only the construction but the creation of an alternative route during the construction is also needed. Therefore, with systematic inspection methods, problems can be realized before the damage exceeds the limit of repair.

Inspections should normally be carried out every two to five years depending on the importance of the bridge. In the case of river bridges, especially for rivers exhibiting remarkable variations in the flow regimes throughout a year, the hydraulic check is suggested to be applied twice a year; one in high flow and one in low flow season. Based on the inspection report, the owner may take action to repair aging parts. However, the risk taken with the negligence of such a study may cause intolerable results. It is also obvious that the small repairs, periodic inspections and maintenance are always economically and practically more feasible alternatives than the reconstruction of the structure or creating a new transportation route all over.

In this study, the evaluation of a bridge structure is divided into two: structural and hydraulic points of view. This distribution is done according to the effect imposed on the structure. One part directly influences the structure and the analysis is carried out for the elements, whereas the other aspect is concerned with the river bed and affects the bridge indirectly. The serviceability component has been included in the structural part because of its direct effect on the structure.

One important concept that should be taken into consideration is the age of the structure. When the priority of the need of the maintenance is analyzed, aging should be one of the complementary factors in the decision. A structure which is close to its economic life should be assessed according to the fact that its service life is nearly completed. Additionally, a graphical presentation of age with respect to condition of the structure can show the deterioration of the structure in time and guide the authorities for the further behavior of the structure.

The quantitative inspection acts as a decisive method for the priority of the maintenance of bridges among each other. Especially adjacent and sequential bridges having the same hydraulic properties can be compared with this quantitative assessment. With this method, the priority of bridges can be designated according to the urgency of repair they need. However, in this proposed system, the complex part is the decisive factor should not only be the overall grades. The sub-elements should always be checked and if any critical value is observed, the structure should be taken to the priority list of maintenance.

7.2 Concluding Remarks

In this study, an inspection methodology is proposed for river bridges. The related literature is reviewed and the current checklist of the General Directorate of Turkish Highways (KGM) is adapted with the help of other existed inspection guidelines in USA. Some new parameters are added or renewed and a new evaluation system is generated according to the needs of the country and the easiness of practical usage. The condition of river stability is assessed using the methodology presented by Johnson et al. (1999). It seems that this methodology covers relatively wide information, which can be obtained from periodic inspections. Therefore, the same hydraulic methodology is also proposed for Turkey with confidence.

If the proposed algorithm is applied systematically, with the results correctly interpreted, the data well organized, and necessary actions taken then the future damages and failures would certainly decrease. With this proposed system, the control would not be a burden to the engineers and the probable dangers and results would be prevented without irreversible consequences. These could be basically daily delays of transportation or economical loss or more seriously; human injuries and losses of lives.

In case studies, some river bridges are selected around Ankara and the checklists are applied to illustrate the use of the new algorithm, including grading, evaluating and archiving. The current conditions of these bridges are assessed and the necessary actions to be implemented are advised.

During this study, it is observed that establishing a database including all these mentioned criteria would be a beneficial improvement in the Turkish bridge network. The inventory information, periodic inspection data and all the visual aid obtained would be entered. With the implementation of a computerized system using such a database, the critical grades of any of the three phases of the inspection can easily be identified. Therefore, it would be possible to focus the attention to the most critical component, e.g. scouring, even if the overall grade of the bridge is relatively high.

The economic analysis of the inspection methodology is out of the scope of this study. However, it is one of the major considerations in an inspection study, especially when a new system is tried to be established. Therefore, working on the economic analysis of this new system and establishing a comparison between the cost of failures and their re-construction with the proposed inspection system may show the advantages of this system clearly. It may be considered as a potential future study.

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APPENDIX A

VISUAL BRIDGE INSPECTION
SAMPLE REPORT

NAME OF STRUCTURE	**:** Esenboğa bridge
CONTROL CUT NUMBER	**:** 140-06
RIVER PASSED OVER	**:** Çubuk Stream
REVIEWED BY	**:** A. BERK
TITLE	**:** Civil Engineer
DATE	**:** 16.03.2006

A.1 INVENTORY

Name	: Esenboğa Bridge
City	: Ankara
Division Number	: Fourth
Bridge Length	: 48.70
Spans	: 15,70 * 3
Construction Firm	: -----
Year of Construction	: 1954, renewed 1979
Type of bridge	: Concrete
Number of beams	: 5 beams per span
Border Width	: 8.50

Name of River	: Çubuk Stream
Average Water depth	: -------
Pier Type	: Concrete
Number of Piers	: 4*2 = 8
Number of Piers in Water	: 8

Inspection Date	: 16. March. 2006
Last Inspected	: -------
Inspector Name(s)	: M. Yanmaz, A. Caner, A. Berk

A.2 INSPECTION REPORT(S)

A.2.1 STRUCTURAL PART

ESENBOĞA BRIDGE (old)					
MAIN BODY COMPONENTS				**EARTH RETAINING COMPONENTS**	
DECK		**SUPPORT**		**ABUTMENT**	
Cracks	5	**Metallic(M) /Elastomeric(E)**	*	Deformation	5
Concrete Disintegration	3	Main Damage	8	Cracks	7
Apparent Reinforcement	4	Support Bed	8	Concrete Disintegration	5
Holes and cavities	9	Loss of elements (M)	8	Apparent Reinforcement	6
Water leakage	4	Anchorage (M)	8	Holes and cavities	5
OVERALL GRADE	**4.00**	Surface arrangement (E)	8	Water and debris abrasion	5
BEAMS		Deformation (E)	8	Scour in foundation	3
Steel (S) /Concrete(C)	C	**OVERALL GRADE**	**5.00**	**OVERALL GRADE**	**5.14**
Deformation	5	**PIERS**		**APPROACH FILL**	
Cracks	5	Deformation	5	Settlement and Slump	7
Rusting (S)	8	Cracks	6	Erosion on road platform	7
Bolts and Rivets (S)	8	Concrete Disintegration	4	Erosion in fill	7
Welding (S)	8	Apparent Reinforcement	7	**OVERALL GRADE**	**7.00**
Concrete Disintegration (C)	5	Holes and cavities	9	**STABILIZATION**	
Apparent Reinforcement (C)	6	Water and debris abrasion	5	Settlement and Slump	4
Holes and cavities (C)	9	Scour in foundation	5	Erosion	4
OVERALL GRADE	**5.25**	**OVERALL GRADE**	**5.33**	Scour in bed level	9
				OVERALL GRADE	**4.00**

SERVICEABILITY COMPONENTS					
COATING		**BORDER - RAILING**		**EXPANSION JOINT**	
Waving	7	**Border (B) /Railing(R)**	R	Noise	7
Tire tracks	7	Cracks in the concrete (B)	8	Water leakage	3
Cracks	7	Concrete Disintegration (B)	8	Deformation	5
Holes and cavities	7	Apparent Reinforcement (B)	8	Holes and cavities	9
OVERALL GRADE	**7.00**	Deformation in railing (R)	5	Loss of elements	5
DRAINAGE		Rusting in railing (R)	6	Loss of function	5
Pipe Damage	7	Deficiency in railing (R)	6	**OVERALL GRADE**	**5.00**
Blockage	7	**OVERALL GRADE**	**5.67**		
Cleanout	7				
OVERALL GRADE	**7.00**				

* The supports can not be counted as elastomeric or metallic. A material similar to styrofoam is used. The overall grade can be evaluated as 5.

Problematic Area(s) **:** Concrete Disintegration at the deck and beams, Scouring at piers and abutment, Railing Deformation, Expansion Joint Problems.

Suggestion(s) **:** Concrete patching, re-decking, renewal of railings.

A.2.2 HYDRAULICS PART

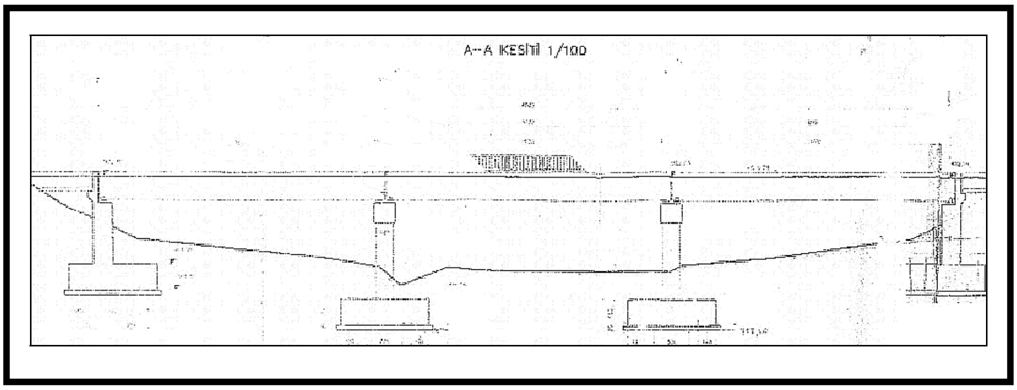
Parameter	Grade	Weighted Coefficient	Weighted grade
Bank soil texture and coherence	**4**	0.6	2.4
Average bank slope angle	**2**	0.6	1.2
Vegetative bank protection	**6**	0.8	4.8
Bank cutting	**6**	0.4	2.4
Mass wasting or bank failure	**6**	0.8	4.8
Bar development	**3**	0.6	1.8
Debris jam potential	**8**	0.2	1.6
Obstructions, flow deflectors and sediment traps	**9**	0.2	1.8
Channel bed material consolidation and armoring	**10**	0.8	8
Shear stress ratio	**12**	1	12
High flow angle of approach to bridge or culvert	**6**	0.8	4.8
Bridge or culvert distance from meander impact point	**2**	0.8	1.6
Percentage of channel constriction	**4**	0.8	3.2

Problematic Area(s) **:** Material Consolidation, Obstructions, Sediment traps

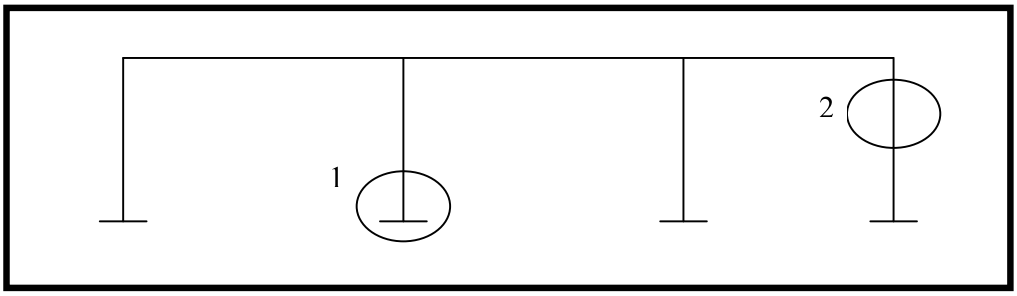
Suggestion(s) **:** Bed rehabilitation

A.3 SKETCH AND PHOTOGRAPHS

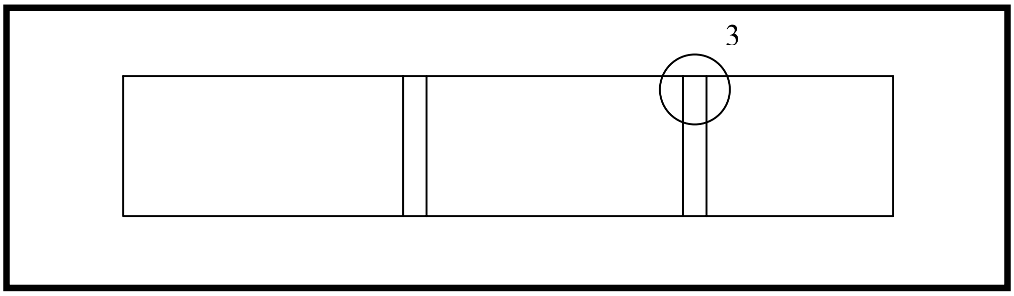
Bridge Name: Esenboğa Bridge



Section View:



Top View:



Comments:

1. Piers: Debris accumulation, scouring occurs at the piers (Figure A.1)
2. Abutments: Apparent reinforcement, concrete disintegration (Figure A.2)
3. Expansion Joints: Due to water leakage, concrete disintegrates (Figure A.3)

………………………………………………………………………………………..

Related Photographs:

Figure A.1 Piers with debris accumulation and scouring.

Figure A.2 The reinforcement and concrete disintegration at the abutment.

Figure A.3 Expansion Joint Details with water leakage and concrete disintegration.

APPENDIX B

SELECTED VIEWS FROM THE CASE STUDIES

- Esenboğa Bridge (old and new)
- Kızılırmak Arch Bridge
- Kızılırmak Bridge (old and new)
- Özçay (Kargılı) Bridge (old and new)

Figure B.1 New Esenboğa Bridge: Accumulated debris between the piers.

Figure B.2 Old Esenboğa Bridge: Accumulated debris between the piers.

Figure B.3 Old Esenboğa Bridge: Damage at the deck due to water leakage.

Figure B.4 Old Esenboğa Bridge: Damage at the deck.

Figure B.5 Old Esenboğa Bridge: The apparent reinforcements at the abutment.

Figure B.6 Old Esenboğa Bridge: The deformed railings.

Figure B.7 Abutments of both bridges (close one is being the old one).

Figure B.8 Scouring at the piers of new Esenboğa Bridge.

Figure B.9 The transportation of debris with the flow.

Figure B.10 Upstream view of Esenboğa Bridges.

Figure B.11 Downstream view of Esenboğa Bridges.

Figure B.12 Downstream view of Esenboğa Bridges.

Figure B.13 Wide concrete arch of Kızılırmak (arch) Bridge.

Figure B.14 Wide crack at the arch of Kızılırmak (arch) Bridge.

Figure B.15 Deformations at the concrete elements of Kızılırmak (arch) Bridge.

Figure B.16 The previous repair work at Kızılırmak (arch) Bridge.

Figure B.17 The disintegrations of concrete at the supporting elements .

Figure B.18 The damage of railings of Kızılırmak (arch) Bridge.

Figure B.19 Upstream view of Kızılırmak (arch) Bridge.

Figure B.20 Downstream view of Kızılırmak (arch) Bridge.

Figure B.21 The abutment of old Kızılırmak Bridge.

Figure B.22 The other abutment of old Kızılırmak Bridge.

Figure B.23 The crack at the deck of old Kızılırmak Bridge.

Figure B.24 The deformation at the deck of old Kızılırmak Bridge.

Figure B.25 The scouring at the piers of old Kızılırmak Bridge.

Figure B.26 The excessive scouring at the piers of old Kızılırmak Bridge.

Figure B.27 Piers of old Kızılırmak Bridge.

Figure B.28 Piers of new Kızılırmak Bridge.

Figure B.29 Upstream of Kızılırmak Bridge.

Figure B.30 Downstream of Kızılırmak Bridge.

Figure B.31 Deformations on the deck of old Özçay (Kargılı) Bridge.

Figure B.32 Deformations at the expansion joint of old Özçay (Kargılı) Bridge.

Figure B.33 Piers and abutment of old Özçay (Kargılı) Bridge.

Figure B.34 Abutment and beams of old Özçay (Kargılı) Bridge.

Figure B.35 Deformed approach fill of new Özçay (Kargılı) Bridge.

Figure B.36 Vicinity of old Özçay (Kargılı) Bridge.

Figure B.37 Upstream of Özçay (Kargılı) Bridge.

Figure B.38 Downstream of Özçay (Kargılı) Bridge.