Second Conference on Smart Monitoring,
Assessment and Rehabilitation of Civil Structures

SMAR 2013

A pilot study for inspection, damage assessment and management of bridges in Turkey

F. Akgül[1], F. Masoumi[2]

[1]Department of Engineering Sciences, Middle East Technical University, Ankara, Turkey
[2]Department of Engineering Sciences, Middle East Technical University, Ankara, Turkey

ABSTRACT: Bridges are one of the most vulnerable elements in the road network and one of the most expensive when a repair or replacement action becomes necessary. Maintenance, repair and replacement actions for bridges become necessary due to aging of these structures in time. Apart from heavy traffic loading, the most prominent cause of bridge aging is material deterioration in time due to environmental factors. In the long term, the bridge engineering is expected to gradually focus more on the inevitable stage of maintaining the existing bridges than the stage of constructing new bridges. In Turkey, a large part of existing bridges must be maintained and repaired properly before they become deficient in the near future. A report has indicated that approximately 50% of bridges in Turkey are 50 years of age or older. This paper reports on research conducted to assess the present status of highway bridges in Turkey. 200 bridges over the highways connected three big cities of Turkey are selected and their condition state evaluations are done based on visual inspections. The authors suggest that maintenance, repair and rehabilitation actions should be done to remedy and eliminate serious damages.

1 INTRODUCTION

Bridges are valuable assets. Defects in their members occur in time, which require continuous attention during the life of a bridge. Natural events such as floods and earthquakes also cause damage. Some bridge components deteriorate and require replacement within the bridge life. The bridge environment can affect durability of bridge materials. Whatever form of construction is used and whatever materials are adopted, sooner or later the effects of degradation begin to appear. There are many contributory factors that affect the nature and degree of degradation such as the structural form, construction materials, quality of construction, design and detailing, atmospheric environment, scour, fire, fatigue, earthquakes, floods, weather, and nature and intensity of the imposed traffic loading. These areas must be addressed, and appropriate maintenance must be carried out to ensure continued public safety as well as to maintain the asset and minimize repair costs.

In Turkey, a large part of existing bridges must be maintained and repaired properly before they become deficient in the near future. A report has indicated that approximately 50% of bridges in Turkey are 50 years of age or older and it causing many problems for traffic users and negatively impacting the development of the country (Masoumi, 2012). Moreover, not much effort is given to the analysis of bridge conditions due to shortages of research funds, lack of care, etc., making it more difficult to overcome these problems. The aim of this paper is to evaluate the current condition of bridges along the government and provincial roads in Turkey in order to find existing defects and their causes, and then to transfer this data to a newy developed bridge management system (named as KYS which stands for BMS in Turkish). The study is performed as part of a comprehensive research project (Tübitak, 2009).

2 METHODOLOGY

2.1 Inspection model

This component of the bridge management system is one of the most important parts, and the best bridge management system in terms of cost analysis or optimization would not yield a good solution without a proper inspection model. All bridges of a transportation network should be inspected regularly, and the condition states of bridges must be defined based on these inspections (Akgül, 2012).

In the bridge network of Turkey, 130 element types are defined as part of this study in which 78 of them are defined as damage element. Damage elements are elements deficiencies of which may cause deficiency in structural behavior of the bridge. All of these 78 elements should be inspected regularly. In Figures 2 through 4, some examples of observed damages during visual inspections are presented.

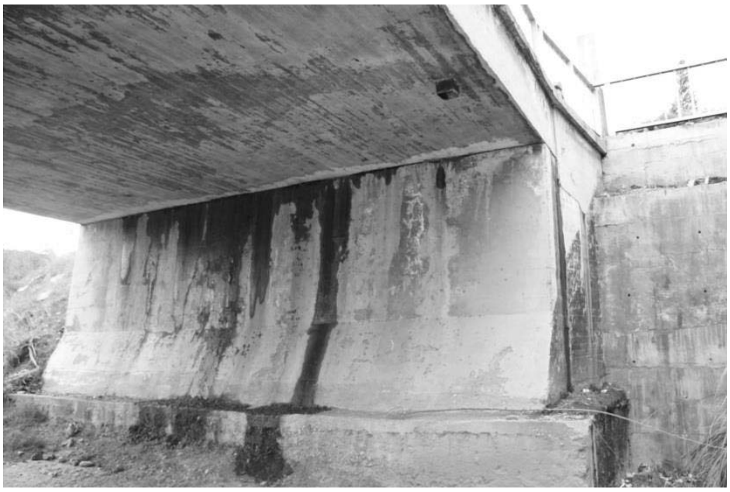

Figure 2. Seepage damage at a side pier wall.

2.2 Condition state model

Four condition states are defined for all element types and also for their relative damage types, 1= No damage or very small damage, 2= Small damage, 3= High level of damage and 4= Critical damage, and the condition state of each bridge is estimated from the condition states of its elements. For each element, there are possible damage types and for each damage type, the condition state of damage are defined. In Table 1, the condition state definitions for the deformation damage type for a reinforced concrete beam is shown as an example.

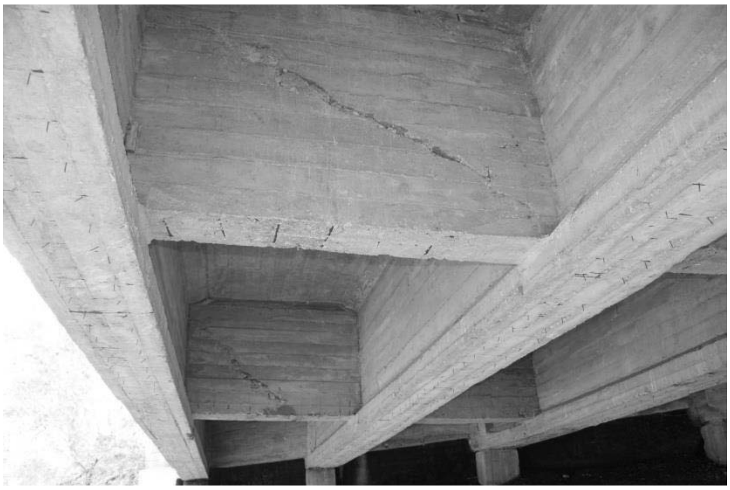

Figure 3. Tansverse beams with critical diagonal cracks.

Figure 4. Exposure of reinforcement under a beam due to construction defects (inadequate cover depth).

Table 1. Condition states and their definitions for deformation in a reinforced concrete beam.

Element Type	Damage Type	Condition State	Definition
Reinforced Concrete Beam	Deformation	1	There is no deformation
		2	Negligible deformation exists at the beam
		3	The deformation does not decrease the load capacity of beam but it decreases the sevice life of the beam
		4	Large deformation exists which decreases the load capacity of the beam

The condition state of each element is calculated from condition states of its possible damage types. For instance, for the reinforced concrete slab, the possible damage types are as shown in Table 2.

Table 2. Possible damage types for a reinforced concrete slab.

Element type	Damage type
Reinforced concrete slab	Crack
	Seepage damage
	Exposure of reinforcement
	Delamination and Spalls
	Dents and Pits

3 CONDITION OF A PILOT GROUP OF BRIDGES IN TURKEY

As part of this study, visual inspections of 200 bridges are conducted and based on these inspections, condition states of all damage types of all bridge elements are determined. Data analyses are performed and expected condition states of all damage types of all elements are calculated. The cumulative distribution functions (CDF) of condition states of elements are also plotted. As shown in Table 3, all element types of selected bridges are in a good condition and condition state of all elements are less than 2. The worst condition state is related to reinforced concrete curb and generally damage type of “exposed reinforcing” has higher condition state in comparison with the other damage types. For piers, damage types of “seepage” and “delamination and spalls” have higher condition states. Metal handrail, asphalt pavement and metal drain pipe elements of bridges are almost in new condition, since their condition states are close to 1.

Cumulative distribution functions of 8 different element types of bridges are presented in Figure 5. Cumulated distribution function of condition states for each element indicates the percentages that element type in different condition states.

Table 3. Expected condition states of all damage types of elements.

Element Type (Expected Condition State)	Damage Type	Expected Condition State
Metal Handrail (1.1)	Missing Member	1.26
	Corrosion	1.02
	Deformation	1.03
Reinf. Conc. Curb (1.66)	Crack	1.41
	Exposed Reinforcing	1.93
	Delamination and Spalls	1.63
Asphalt Pavement (1.17)	Dents and Pits	1.25
	Ondulation	1.30
	Tire Tracks	1.12
	Cracks	1.02
Metal Drain Pipe (1.14)	Obstruction in Pipe	1.30
	Inlet Damage	1.04
	Missing Member	1.06
Reinf. Conc. Slab (1.25)	Dents and Pits	1.09
	Crack	1.19
	Exposed Reinforcing	1.46
	Delamination and Spalls	1.39
	Seepage Damage	1.06
Reinf. Conc. Beam (1.34)	Dents and Pits	1.29
	Crack	1.39
	Exposed Reinforcing	1.66
	Delamination and Spalls	1.31
	Deformation	1.04
Reinf. Conc. Pier (Middle) (1.24)	Dents and Pits	1.09
	Crack	1.21
	Exposed Reinforcing	1.12
	Deformation	1.00
	Delamination and Spalls	1.29
	Seepage Damage	1.60
Reinf. Conc. Pier (Side) (1.25)	Dents and Pits	1.01
	Crack	1.28
	Exposed Reinforcing	1.15
	Deformation	1.02
	Delamination and Spalls	1.34
	Seepage Damage	1.61

As an example, Figure 5 (a) shows that approximately 80 percent of condition state of metal handrails is 1, 12 percent is 1.33, 3 percent is 1.66 and 5 percent is 2. Cumulative distribution functions of elements indicate the expected condition states of elements. Fig 5 (b) shows that reinforced concrete curb has higher condition states and maintenance action will be necessary for this element.

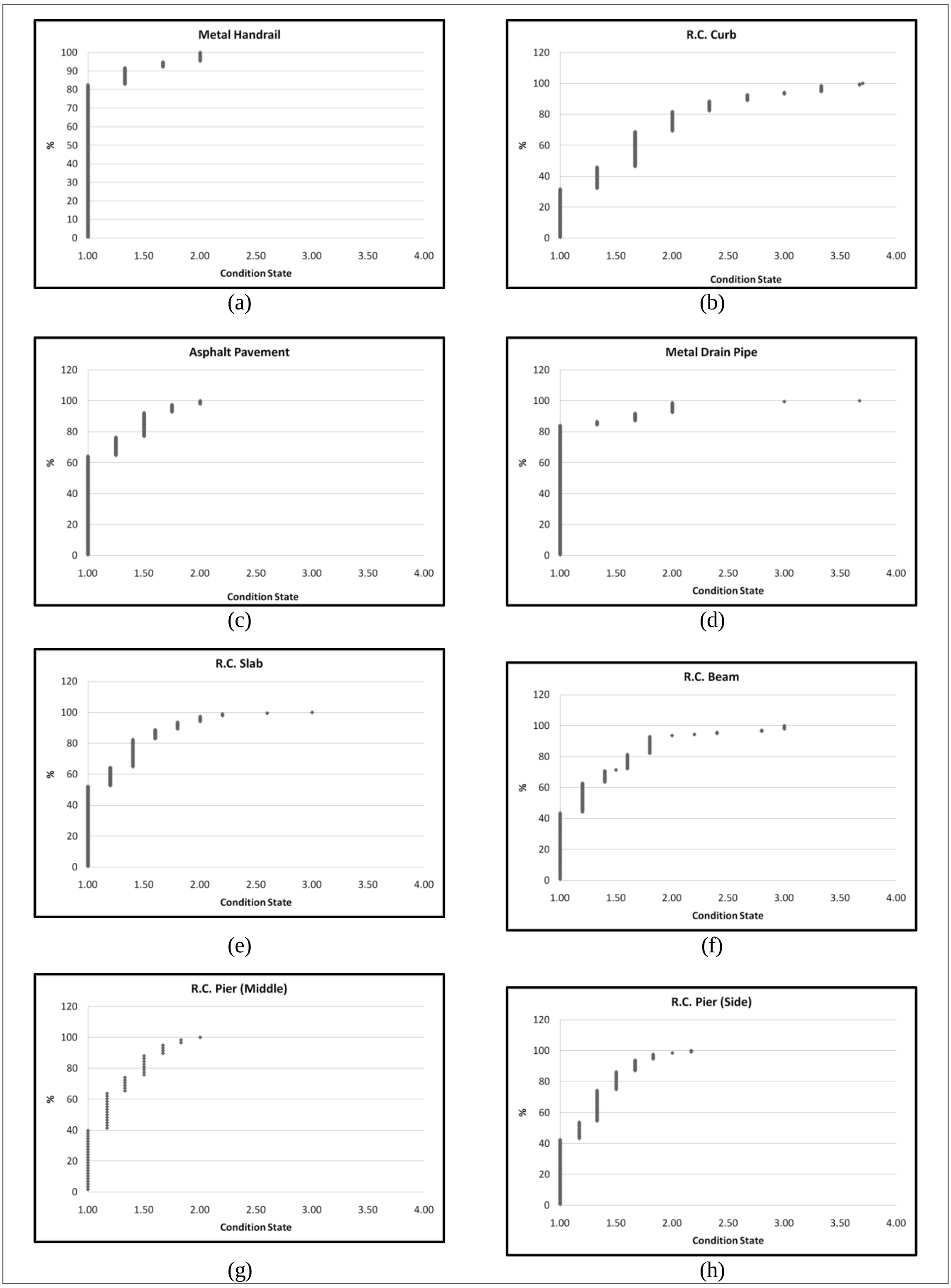

Figure 5. Cumulative distribution functions of condition states of element types.

4 CONCLUSIONS

This paper presents a study on the condition evaluation of a pilot group of bridges located along the state and provincial roads in Western Turkey. 200 bridges of various types are selected and condition states of bridge elements are determined by visual inspections. Analysis of condition state data shows that all elements of bridges within the pilot study are generally in good condition with some exceptions. “Seepage”, “exposed reinforcing” and “delamination and spalls” are observed to be the most common damage types of the reinforced concrete element types for the pilot bridge group. Exposed reinforcing at girder bottoms due to construction defects are also common. Metal handrails, asphalt pavements and metal drain pipes are observed to be generally in good condition except obstruction of drain pipes are commonly observed. Furthermore, it has been observed that most of the expansion joints are completely covered with additional asphalt layers.

5 ACKNOWLEDGEMENTS

The financial support, provided by TÜBİTAK (The Scientific and Technological Research Council of Turkey) KAMAG Group (Public Research Grant Committee) through the Project 108G018, is gratefully acknowledged. The author acknowledges the efforts of Mr. Tayfun Hız and the continued support for the project from the Environmental Tectonics Corporation Information Systems (ETC-IS A.Ş) during the software development throughout the project duration. The writer is also grateful for the kind assistance provided by Mrs. Tuba Gürgen in the Bridge Inspection Department of the General Directorate of Highways. The opinions and conclusions presented in this paper are those of the writer and do not necessarily reflect the views of the sponsoring agency.

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