Evaluation of Deterioration on Steel Bridges Based on Bridge Condition Ratings

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Recent developments in Bridge Management Systems (BMS) and in Life-Cycle Cost (LCC) of bridges, have raised the need for evaluation procedure of future condition (Deterioration) of a bridge. Predicting future deterioration is not an easy task due to limited past data to extrapolate from and also due to difficulty in measuring actual deterioration such as section loss of steel on an actual steel bridge. Also, increase in live load and reduction of resistance are random variables, thus a probabilistic approach should be adopted for determining the future deterioration.

Due to difficulties in evaluation of future deterioration on steel bridges, accepting uncertainties within a reasonable error, a deterministic procedure using bridge condition rating can be a useful tool for projection of future condition of bridges to identify repair and maintenance needs.

The object of this paper is to determine applicability of evaluating deterioration of steel bridge components based on Bridge condition ratings. Bridge condition ratings of bridge components show wide variation for bridges of same age and does not directly correlate well with the age of the bridge and/or deterioration of the bridge. High uncertainty can be reduced by breaking down the rating and by sensitivity analysis. From refined condition rating data, generalized deterioration profile of structures based on age can be derived. Examples are shown for sample bridges in USA. Approximately, 3,000 short to medium span steel bridges were listed in the inventory database.

Results show wide variation of rating factors but by subdividing the Bridge condition ratings for various categories general deterioration profiles of steel bridges can be determined.

Keywords : *steel bridge, deterioration, condition rating, corrosion*

1. Introduction

Assessment, repair and rehabilitation of bridges are increasingly important topics for bridge engineers in many countries in the effort to deal with the deteriorating infrastructure. The major factors that have contributed to the present situation are: age, inadequate maintenance, increasing traffic load spectra and environmental contamination. The deficient bridges are weight restricted, width restricted, repaired or replaced. Any of these measures clearly involve considerable economical and safety implications. To avoid high costs of replacement or repair, the assessment must accurately reveal the present load carrying capacity of the structure and predict loads and any further changes in the capacity (deterioration) in the applicable time span. At the same time the assessment must ensure that safety is maintained. There is a growing need for efficient procedures. The optimum decision making process about repair, rehabilitation or replacement should be based on the life cycle performance, with rational acceptability criteria and state of the art methodology.

The currently available bridge assessment code procedures only deal with the adequacy of the structure at the time of assessment. Radically new procedures are therefore required to examine whole life related performance. Such procedures will also be valuable for determining cost effective future maintenance strategies for different types of bridges and other highway structures.

Recent developments in Bridge Management Systems (BMS) and increasing interest in Life-Cycle analysis of bridges, have raised the need for evaluation procedure of future condition (Deterioration) of bridges. Predicting future deterioration is not an easy task due to limited past data to extrapolate from and also due to difficulty in measuring actual deterioration such as section loss of steel on an actual steel bridge. Also, structural performance depends on load and resistance parameters which are time-varying random variables. The variation is due to natural causes (loads, strength of material), deterioration (corrosion) and other reasons (growth in legal load limits). Thus a probabilistic approach using reliability methods should be adopted for determining the future deterioration. But probabilistic methods are difficult to apply for general engineers to apply and requires much data for each random variables.

Due to difficulties in applying probabilistic procedures for general engineers, a deterministic procedure using bridge condition rating can be a useful tool for projection of future condition of bridges to identify repair and maintenance needs.

The object of this paper is to determine applicability of evaluating deterioration of steel bridge components based on Bridge condition ratings. Bridge condition ratings of bridge components show wide variation for bridges of same age and does not directly correlate well with the age of the bridge and/or deterioration of the bridge. High uncertainty can be reduced by breaking down the rating and by sensitivity analysis. From refined condition rating data, generalized deterioration profile of structures based on age can be derived. Examples are shown for sample bridge data in USA. Approximately, 3,000 short to medium span steel bridges were listed in the inventory database. in steel bridges,

2. Procedure

A sample Bridge Inventory Database in USA is selected for this example. Selected database contains over 3,000 steel bridges of short to medium span (~100 m), with earliest bridge built in 1900's. The corrosion environment for the considered region is a high corrosion environment due to use of deicing materials during Winter times.

Deterioration of steel bridges depends on atmospheric environment, exposure of components (interior or exterior), protective treatment of steel, influence of de-icing, and traffic volume. Type of material used (weathering steel, carbon steel, etc.) and construction details may effect the overall performance of the bridge. Corrosion is one of the most important causes of deterioration for steel bridges. The primary cause of corrosion is the accumulation of water and salt (marine environment and deicing salt) on bridge steel.

With the limitation of available data four parameters are considered. Mainly, Superstructure condition rating, Paint condition rating, Federal inventory rating and Average Daily Traffic (ADT). Age of the structure was calculated by the difference between the year the bridge was built (or rebuilt) and inspection date. Same as paint age as difference between the year paint was re-applied and inspection date. Also, many bridges are not repainted during lifetime due to limited funds and lack of maintenance personals. Data was sorted and non-applicable data was filtered.

2.1 Condition rating of paint

Condition rating of paint verses age of paint is shown in Fig. 1 for the selected bridges. Rate 9 is the as painted (new) condition while rate 0 represents full deterioration. As it can be seen, wide variation exists in ratings of paint for bridges of same age. Also, rating degradation do not correlate well as with the age of paint.

High uncertainty can be reduced by subdividing the obtained data in details. For this purpose average daily traffic(ADT) will be selected for the parameter. If available, average daily truck traffic(ADTT) is preferred to give better results. Since bridge locations were selected from same high corrosion environment, obtained paint condition ratings were categorized for various ADTs: namely, ADT less than 1,000, ADT between 1,000~10,000, ADT in the range of 10,000~50,000 and finally for ADT of 50,000~100,000. The results are shown in Fig. 2~Fig. 5, data are statistically calculated to shown the average and Standard deviation difference from the average.

As it can be seen from the figures, there exists a general rating degradation and a profile can be drawn. Also, the average life span of paint is in the range of 15years for the selected bridges as shown in Fig. 3 ~ Fig. 5. It should also be noted that there exists a wide variation of uncertainty in the data.

Also, comparing the average condition ratings of paint and steel girders for the same bridge, there exists a linear degradation relationship between the two parameters as shown in Fig. 6.

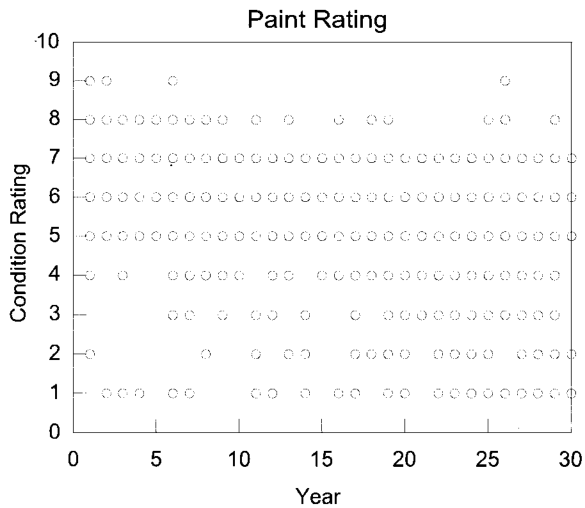

Fig. 1. Paint Condition Rating

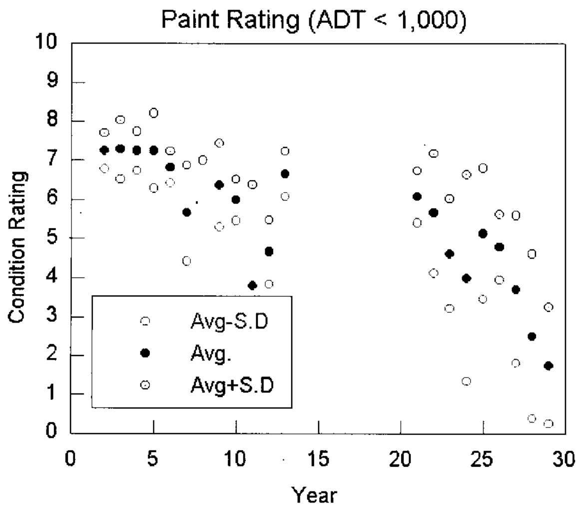

Fig. 2. Paint Condition Rating (ADT <1,000)

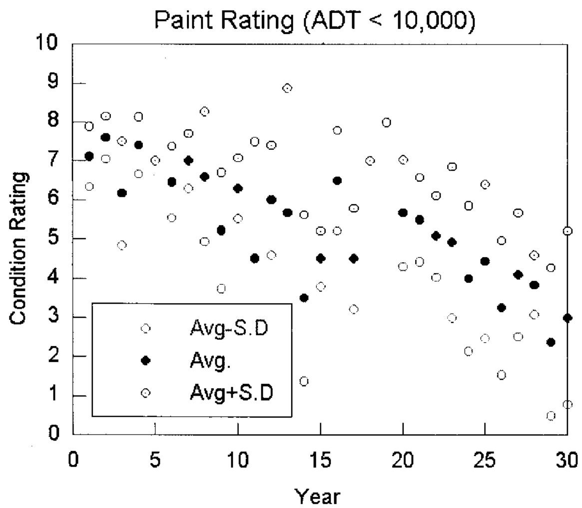

Fig. 3. Paint Condition Rating (ADT <10,000)

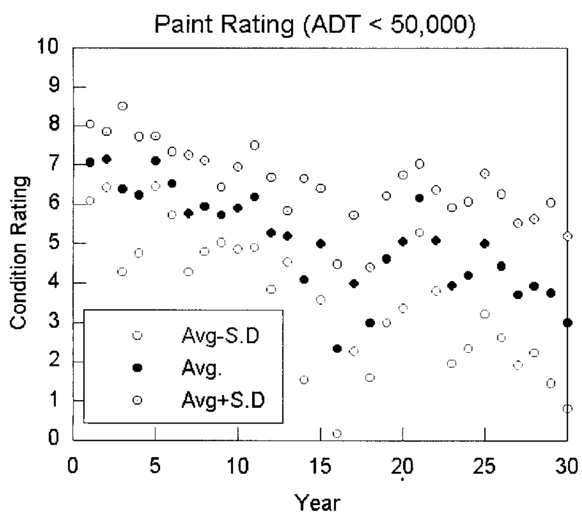

Fig. 4. Paint Condition Rating (ADT <50,000)

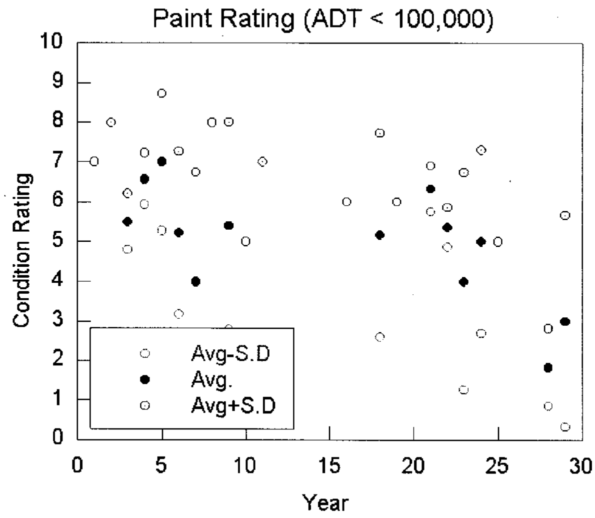

Fig. 5. Paint Condition Rating (ADT <100,000)

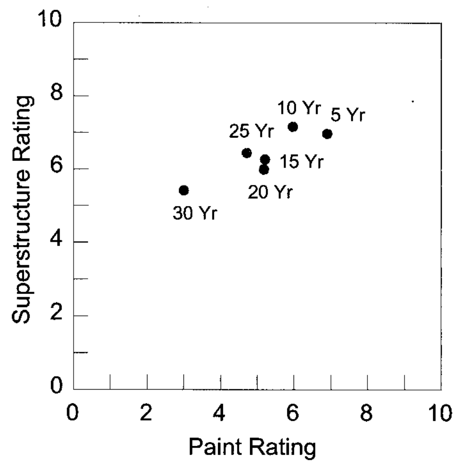

Fig. 6. Condition Rating of Steel Girder and Paint

2.2 Condition rating of steel girders

Deterioration of steel bridge occurs mainly on concrete deck and on steel girders. Thus status of steel girders are a crucial factor in determining deterioration of steel bridges. Condition ratings of bridge superstructure (girders) are plotted for age of structures in Fig. 7. Bridge age was determined by calculating the difference between the year the bridge was built (or rebuilt) and the inspection date. Rate 9 is bridge with no deterioration on steel girders while rate 0 represents full deterioration (out-of-service). As it can be seen, wide variation exists in ratings of girders for bridges of same age. Also, rating degradation do not correlate well as with the age of structure.

High uncertainty can be reduced by subdividing the obtained data in details as shown in previous case. The obtained data is divided based on average daily traffic (ADT). For low volume traffic of ADT less than 1,000,

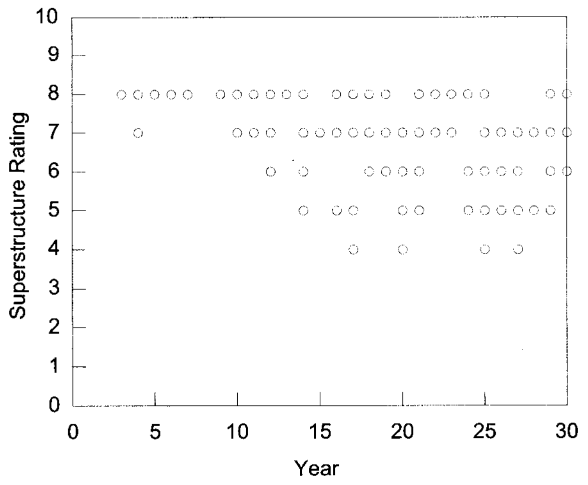

Fig. 7. Condition Rating of Steel Girders

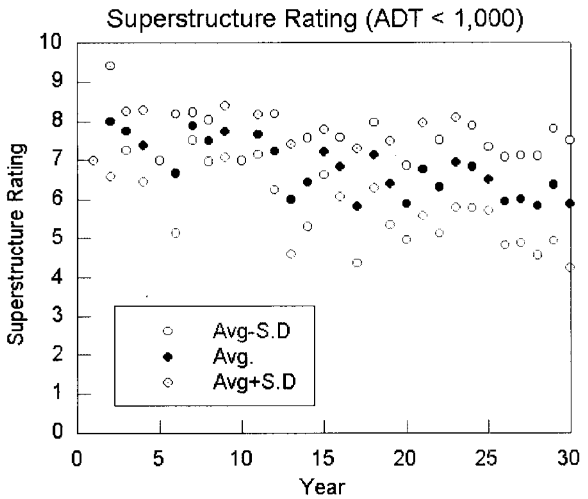

Fig. 8. Condition Rating of Steel Girders (ADT < 1,000)

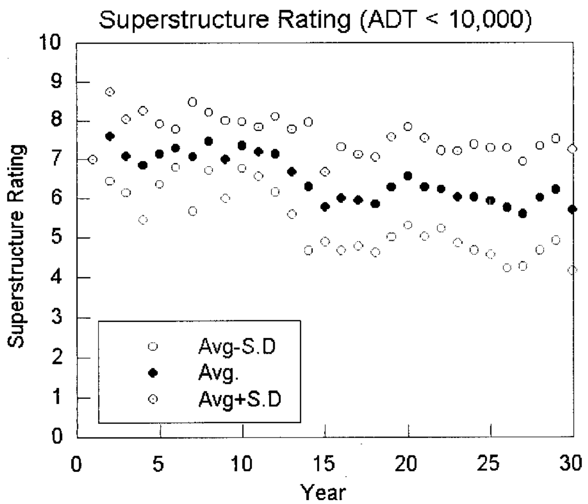

Fig. 9. (ADT < 10,000)

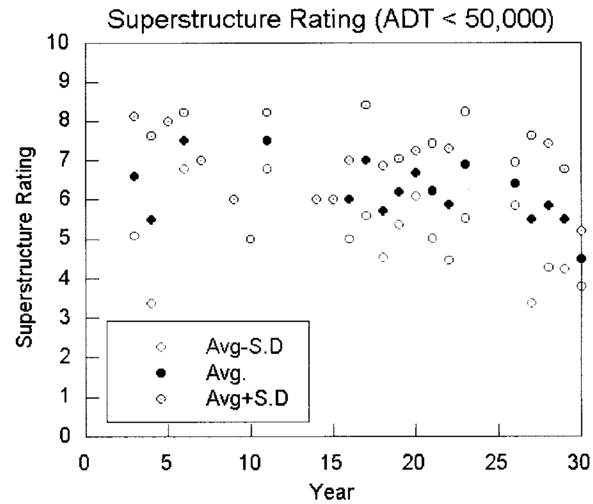

Fig. 10. Condition Rating of Steel Girders (ADT < 50,000)

medium volume traffic of ADT between 1,000~10,000 and high volume traffic of ADT in the range of 10,000~50,000. Over 50,000 was not considered due to insufficient numbers in the data. The plotted results are shown in Fig. 8~Fig. 10, data are statistically calculated to shown the average and Standard deviation difference from the average.

A degradation profile can be visually seen for the average deterioration of steel girders.

2.3 Inventory rating of bridge

Finally, same procedure was applied for Inventory rating of bridges. Inventory rating is given in Eq. 1.

$$(R_{act} / \gamma_R \quad \Sigma\gamma_{fD} D_i) / \gamma_{fL} L \qquad (1)$$

where R_{act} is the load capacity, γ_R are resistance factor given in the design code applied, γ_{fD} and γ_{fL} are load factors for dead load and live load, respectively, as specified in the applied design code, D_i is the moment (or shear) caused by dead load and L is live load moment (or shear) due to design live load. For the selected bridges HS-20 loading was used based on AASHTO design guide.[1] Inventory ratings are shown in Fig. 11 and again for various ADT in Fig. 12~15.

It should also be noted that degradation profile of average rating of steel girders have relatively same trend to theoretically developed profiles in available literature.[2),3)]

With the obtained general profile for average data, a general engineer can project future condition of the considered structure based on the profile. Accepting uncertainties within reasonable error, such simple deterministic approach can be used for determining future condition of the structure.

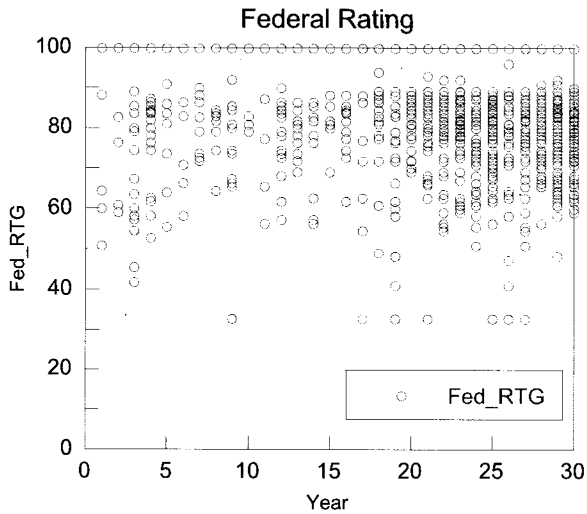

Fig. 11. Inventory Rating

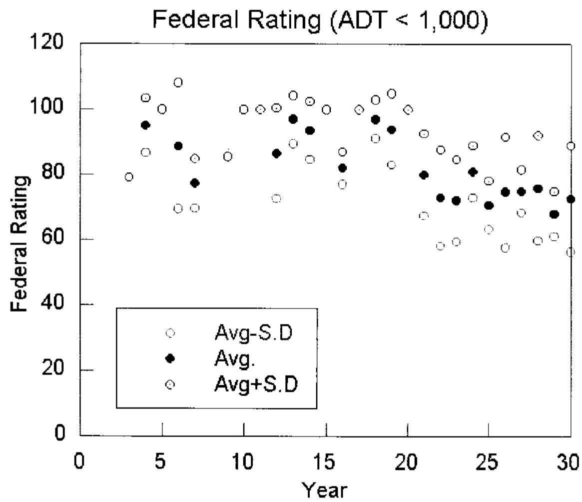

Fig. 12. Inventory Rating (ADT < 1,000)

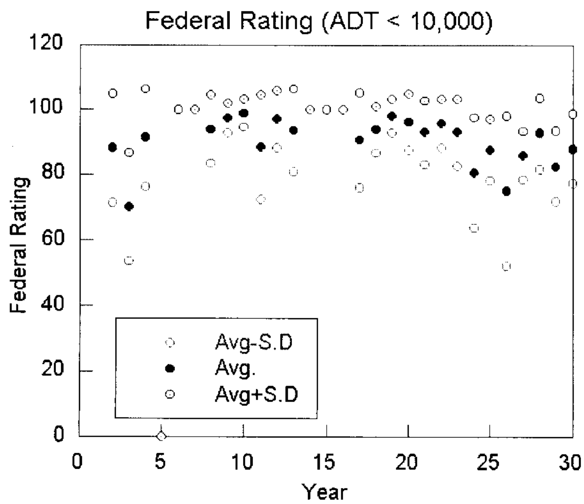

Fig. 13. (ADT < 10,000)

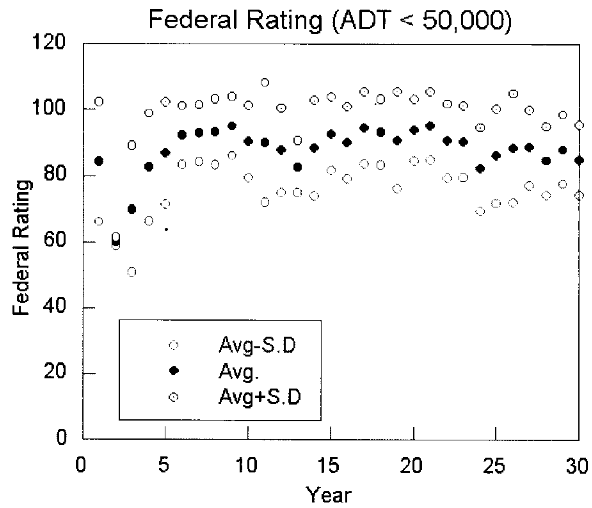

Fig. 14. Inventory Rating (ADT < 50,000)

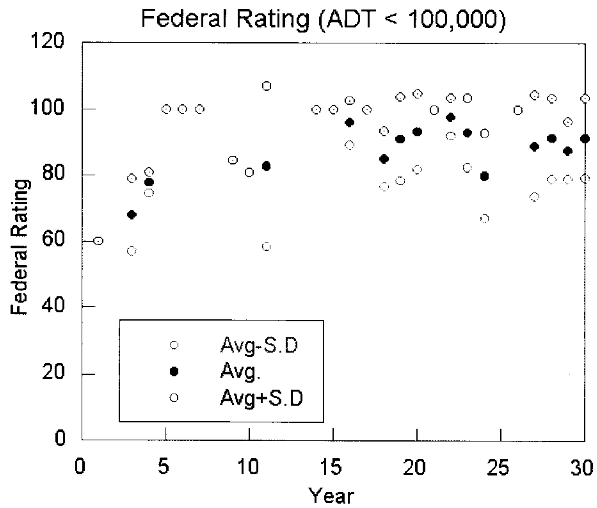

Fig. 15. (ADT < 100,000)

3. Conclusions

(1) A simple deterministic procedure is given for determining deterioration of steel bridges based on refine sorting and filtering of condition rating of bridge main components.

(2) Results show relatively good agreement with theoretical results from available literature and general deterioration profiles can be determined for easy access to general engineers.

Acknowledgement

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