

Process of inspecting road bridges in Ho Chi Minh City - Part 1: Existing inadequacies in the current process

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Abstract:

Quality inspection of traffic works, including quality control of simple bridge construction, is always a big problem in the management process of current authorities. This article will evaluate the outstanding issues in this current demand test standard, in which the study will build an overview evaluation model of the demand test standard and identify the outstanding shortcomings. The analysis from the article shows that the inspection process has problems that need to be supplemented and improved to both meet the requirements according to the process and properly represent the scientific nature of the problem. In addition, the inspection standards need to strongly eliminate problems that are not really necessary or that do not affect the quality of the work at the time of the survey. The issues investigated from the testing standards in the following sections include: remaining shortcomings in the existing bridge testing process; necessary additions in the bridge inspection process based on the development of science and technology; the bridge health monitoring system has been bringing about important decisions in assessing the quality of the bridge construction; the existing demand testing process – how to better match the rate of change of the present.

Keywords: Inspection; simple bridge construction; natural frequency; damping coefficient; deformation.

1. Introduction

Highway constructions, which includes the bridges, always play an important role in all society's activities. The damages of the bridges are not only causing the traffic stagnation and great economic loss, but also threatening the lives of people who are moving on the bridge [1]. As assessed in the statistics from 2000 to now, over 100 big bridge collapses, of which have brought the death to thousands of people and tens of thousands injured. The number of dead and injured people have been yearly increasing, the ratio is getting more and more serious. Also according to [2] on May 31, 2016 in India, the Vivekananda Flyover Bridge was broken, caused over 27 deaths and more than 80 injured, the cause that has been investigated up to now has indicated the errors in process of both construction and design. Even in Vietnam, since the beginning of 2016 until now, a series of bridge collapses have caused a lot of loss to either people

or property. According to the timeline, the collapse of the Can Tho bridge span [3] was one of disasters concerning between the road and the bridge and the most serious construction accidents in Vietnam occurred on September 26, 2007, in My Hoa commune, Binh Minh town, Vinh Long province. Through the above incidents, we could better understand the importance of bridges. Therefore, the task of monitoring the bridge condition is playing an important role as a permanent mission of the management agencies so as to ensure the absolute safety during their operation process.

Vietnam is a country with a speed of high economic growth in the world, along with the rapidly increasing urbanization rate, especially grows in the southern region and Ho Chi Minh City is a typical one, many bridge projects have been carried out of which rapidly sprung up so as to meet the socio-economic activities. The key economic regions have already been connected by bridges

with the adjacent areas so as to form the specific economic zones. According to statistics from the Ministry of Industry and Trade (in 2009) more than 95% of domestic goods are transported by road, ensuring the bridge systems in stable operation is important and practical. Apart from constructing the new bridge systems of which have been accounting for tens of thousands of billions of dong per year, the inspection, repairing and maintenance of existing bridges imposed huge costs on urban managers and people. Because of the characteristics of many interlaced rivers, traffic throughout the country greatly depends on the bridge systems [1]. Many bridges are in a status of "permissible overload" by the traffic survey during construction process, in which the main reason is due to the great changes and differences since the last twenty years in terms of estimated traffic volume when designing and actual traffic volume taking place in current...in general, the bridge systems in this area is in the degraded condition or severely degraded status. Because the speed of deterioration of the bridges is always an inverse paradox to the economic growth rate in case the traffic and freight transport also increases respectively. Therefore, apart from the measures of building the new bridges, it is necessary to maintain the integrity of the existing bridges on the basis of properly repairing measures. Currently, the basis to decide the priority in the repairing plan is to conduct an inspection. The inspection process is strictly stipulated under the evaluation standards so far [4]-[23]. According to this stipulation, the inspection is mainly based on the static bearing state [4]-[8]. The

generated load based on the expected load impacted on the bridge, then measurements will be taken so as to verify the bridge quality. The useful advantage of this method is to give us the initial mechanical data under the action of a predetermined force impacted on the bridge. Under the action of this load when we have clearly known the values and their action plans specified in accordance with the Standards. According to this measure, the expected load withstood on the bridge, the load bearing capacity is shown by the measured data: span deflection, deformation, impulse coefficient, natural frequency, displacement parts such as abutments, bearings, piers [8]-[15]. This measure determines the actual values of the mechanical parameters at the time of the Testing organization. In case the inspection is implemented according to the prescribed cycle, the assessment of the operating ability and the forecast of the degradation progress can be controlled. However, one of the disadvantages of the current procedure for bridge inspection is the measured data obtained in the static condition, except for the natural frequency value and the impulse coefficient which are determined by generating the vibration condition by an impulse. Apart from that, the load test cases (values, load placement plan) cannot cover all possible real conditions. Because of the difficulty and cost, this method is only used in the "main" inspections. The inspection cycle is temporarily regulated by the People's Committee of Ho Chi Minh City from 3 to 10 years depending on each type of bridge. Table 1 shows the inspection time according to the bridge group in Ho Chi Minh City area.

Table 1. Inspection time of different bridge groups in Ho Chi Minh City area [20]-[23].

| No | Bridge structure type | Bridge put into operation under 20 years (Once/year) | The bridge has been put into operation for 20 years or more (Once/year) |
|----|--|--|---|
| | | Inspection | Inspection |
| 1 | - Regular reinforced concrete bridge | 10 | 7 |
| 2 | - Prestressed reinforced concrete bridge | 8 | 5 |
| 3 | - Steel girder bridge | 6 | 4 |
| 4 | - Combined steel-concrete bridge | 6 | 4 |

| N ₀ | Bridge structure type | Bridge put into operation under 20 years (Once/year) | The bridge has been put into operation for 20 years or more (Once/year) |
|----------------|--|--|---|
| | | Inspection | Inspection |
| 5 | - Reinforced concrete slab girder bridge | 6 | 4 |
| 6 | - Arch bridge | 6 | 4 |
| 7 | - Steel truss bridge | 4 | 3 |
| 8 | - Bridges have other types of structures | 4 | 3 |

In fact, the bridge's actual working condition is dynamic. Except for pedestrians and bicycles, almost all other motor vehicles traveling on the bridge also cause the vibration on the bridge. The vibration amplitude will be different from the displacement value when the load is statically placed on the bridge or in other words, the current inspection method has many backlogs which are not matched with the criteria according to the current development trend. In addition, the time interval between two inspections is quite long which can arise so many potential dangers during the exploitation of bridges. Because of a large budget when conducting the bridge inspection, small and medium-sized bridges are usually only inspected twice during their operation (Taking inspection when the new bridge is built and in case of being intended to demolish that for new bridge construction). Therefore, the actual status between the two inspections can not be determined resulted in making difficulty for the technical management agency to decide the time organization as well as to designate specific parts needed to have maintenance in order to make decisions on technical measures to repair. Due to the economic urgent feature when the budget is continuously cut led to the situation of periodic inspection is now less and less. Consequences from not being regularly inspected, a series of bridges collapsed only in 2016, which can be mentioned as: (Bridge collapse information needs to be supplemented). Therefore, it is necessary to give out a suitable method to modishly assess the bridge condition so as to bring the

significance of the assessment quality with an acceptable cost to surmount the situation of too poor information in assessing the current bridge quality. Simultaneously, we need to provide proper methods to classify the degrees of damages in order to the bridge's main load-bearing parts (span, pier, abutment) in order to focus on reasonable repair costs considered as an urgent need for Ho Chi Minh City in both present and future [24].

Based on the outstanding backlogs in the bridge inspection standards in assessing the quality of exploitation in recent years when the advancement of science and technology is strongly growing, this article is to provide information and analysis about the nonconforming issues in the current inspection standards. The article is divided into several different sections, including:

- Part 1: Outstanding backlogs in the existing bridge inspection process.
- Part 2: Necessary supplementations in the bridge testing process based on the development of science and technology.
- Part 3: Bridge health monitoring system has been bringing the important decisions in assessing the quality of bridges.
- Part 4: Existing bridge inspection process – how to better match the current rate of change.

In this part, the research focuses on assessing the outstanding issues and the too old parameters without being updated.

2. Methods applied for assessment of construction quality

In the process of assessing the quality of bridges, the sequence of works is arranged in order from low to high, including [14]-[19]:

- Checking and concluding whether or not the presence of defects on the mechanical system in order for us to undertake timely assessment measures, including: monitoring, minor and major repairing, and maintenance.

- In case the bridge girder is determined to have the defects, the construction units need to locate, or localize the positions of the defects or to be suspected to have the defect for repairing and maintenance.

- The existence of such defects must be assessed about the ratio of affecting on the bridge's structure operation or not, furthermore, we will have to determine the degree of damage to conduct regular inspection and periodical testing.

- The last step in the problem of defect identification on the bridge is to conduct the failures through the inspection process in case of being necessary to give timely warnings in order to minimize the harm to people and property when failures occur, especially for bridges.

- Many different methods have been formed to carry out the above steps for the problem of identifying the existence of defects on the bridge, including:

- Manual inspection is carried out by simple methods such as visual inspection or by single-purpose equipment: this is only a qualitative measure mainly for bridge managers to check daily, weekly, quarterly or predetermined cycles depending on the importance of the bridge. When patrolling on the bridge, the staff can detect abnormalities and warn people and vehicles moving on the bridge. The advantage of this method is simple, and easy to implement, the initial investment cost for the inspection is low, but this method has many disadvantages: no damage is detected inside the details, the material's mechanical changes can not be assessed. Despite the

disadvantages mentioned above, manual inspection must be an indispensable measure.

- Ultrasound inspection: After visual inspection, ultrasound is one of the oldest methods up to now. This measure's scientific basis is to transmit down an ultrasonic wave pulse beam into the surface needed to be examined. Wave analysis obtained from the inspected object can identify defects through the difference between two ultrasonic waves. This is a fairly simple measure and is easy to implement, which does not require too many labors and saves a lot of money when conducting an inspection. However, it is quite outdated and the results are not accurate for microscopic defects, and defects are deeply lying inside the object.

- Checked by periodic inspection method. Quality inspection of bridges includes the activities to check and determine the quality or assess the quality conformity of bridges with the requirements compared to design, technical regulations and standards through the review, the current status of bridges by visualization combined with analysis and evaluation of tested data. Measures to periodically survey the mechanical behavior of bridges. This measure is responsible for assessing the bridge's actual working capacity. The bridge verification process has been codified by State documents which allow the assessment by quantifying the bridge's working capacity. During the implementation of this measure, several devices are used to allow the quantitative assessment of the condition: deformation gauges, deflection meters, relative displacements of bridge components (abutment displacements, support subsidence,...), natural frequency. The advantage of this verification method is to give bridge's deformation data under loads has given us the real known values and their action plans expected to cause the most dangerous deformation. The disadvantage of the current procedure for the bridge verification is the data are obtained in a static condition, except for the natural frequency value and the impulse coefficient determined by

creating the vibration from an impulse. Moreover, the load test cases (values, especially load placement plan) cannot cover all possible scenarios; Bridge inspection is carried out periodically under the circular issued by City People's Committee in Document No. 24/2003/QD-UB on date of 3/3/2003 about "Promulgate the temporary regulations on the inspection of road bridges in "Ho Chi Minh City" area stipulated the interval between two inspections for each type of bridge structure, of which the nearest time is 3 years, the furthest one is 10 years. The interval between two inspections is quite long, so the condition between the two verifications can not be determined, resulted in difficulty for the technical management agency to decide the time to organize the test, as well as measures to take for which specific parts of the bridge needed to have maintenance and repairing.

- Test by vibration method which is a measure to survey the bridge's behavior during actual traffic through the vibration measurement. The measure has not been widely applied and has not been legislated yet. For this measure, it is possible for us to see the values showing the actual bearing process caused by the real load system when vehicles are moving on the bridge in a very diverse and dynamic way. The scientific basis of this method is often based on the vibration change in case the defects arise on the bridge. According to [25], the defects will change characteristic parameters of the vibration when existing in the beam, such as: the value of natural frequency decreases because this value is directly proportional to the beam's stiffness EJ_x and simultaneously will change the vibration modes of the defectively mechanical system compared to the origin [26]. Thus, people look for changes in vibrations in order to find the defects and identify them. The advantages of the behavior survey method during the actual traffic are: allowing to detect the actual overload situation (beyond the bridge's allowable capacity); recording the evolution of mechanical

parameters; collecting the recorded data and their behavior so as to make it possible to find places in which bridge's tolerance is weakening and the speed of deterioration in order to help with decision making and control planning for bridge quality and reasonable repairing plan. However, this method also has many backlogs because it greatly depends on the "sensitivity" of the device and the processing method when the system is greatly influenced by noise.

- Testing by method integration with many different measures will create a large system with many different features. Clearly, the above analysis has demonstrated the old measures have partly met the needs and degree of urgency given by the managers because these measures are not comprehensive without properly and fully reflecting the bridge's different bearing status during operation. In the world, more than last 20 years, many systems relative and continuous measure parameters have arisen under actual traffic load conditions [27], often called bridge's "health monitoring" systems, distributed mainly in developed countries such as the US, Canada, EU and typically in Korea and Japan, which are Asian countries with many interlaced river and sea systems. For these systems, the behavior of the bridge in the presence of traffic vibration with frequencies depending on the traffic condition. Although it is not possible to determine the true value of the load, capturing the actual vibrational parameters of the bridge allows one to visualize the behavior of the whole system and thereby infer the "health" state [28] as shown in figure 1 [29]. The data used for analysis can be from specialized electronic devices. With superior features compared to the old measures, when the system integrates many different measures to bring high efficiency during use. For the operation process, the system has regular warning and monitoring features (24/24), which includes monitoring when there are serious environmental problems such as wind, storms, snow, etc. This system has high installation costs, maintenance costs, and an operating life cycle

that is short (usually only operating for 2-3 years/system). Thus, these systems are only installed on large bridges, cable-stayed bridges,

and arterial bridges. Therefore, small and medium bridges are difficult to apply.

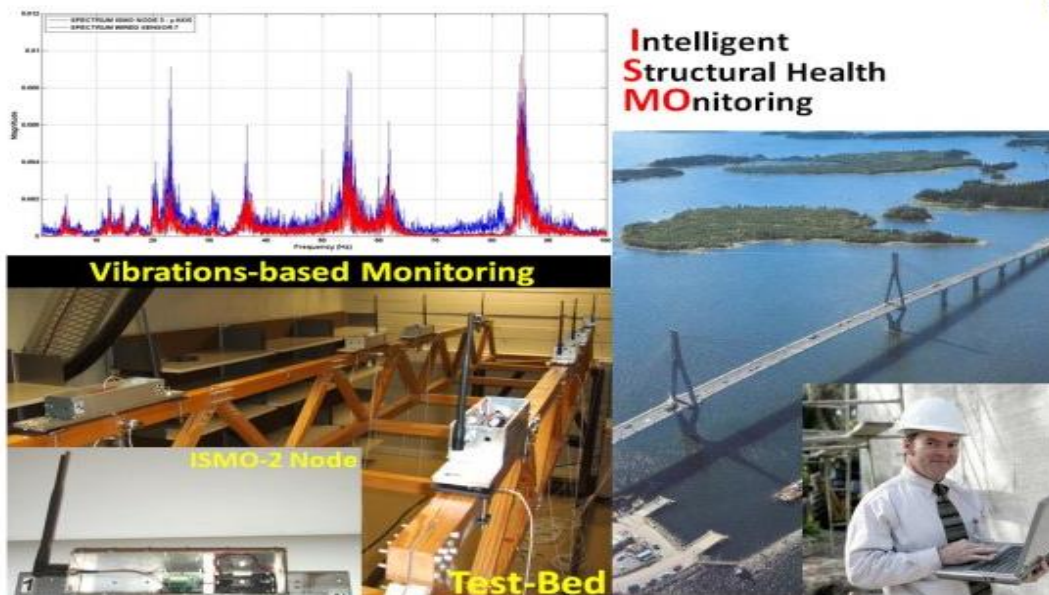


Figure 1. HMS system at Dong Hai bridge, China [29].

Considering the economic and social development situation in Vietnam, it is more difficult to apply these measurement systems and the demand system here. According to Ho Chi Minh City Department of Transport statistics in 2013, there were over 1,000 bridges of different types and sizes here alone as shown in figure 2. Most of the bridges are small and medium-sized,

with simple span structures spanning canals. However, with the urgent requirement to apply scientific and technological advances to regular bridge maintenance and repair, many research groups have been implementing systems to monitor the operation of the bridge 24 hours a day [30].



Figure 2. Signal reception system of Saigon Bridge [30].

3. The main backlogs in the inspection standards for simple bridge construction

The inspection is carried out according to procedure and coordinated by the traffic management unit and subsequent subdivisions. The management model shown in figure 3 shows

a typical bridge management model in the HCMC area. Typically, these bridge projects are managed in three layers: the main management unit, the affiliated unit, and the regular bridge management team.

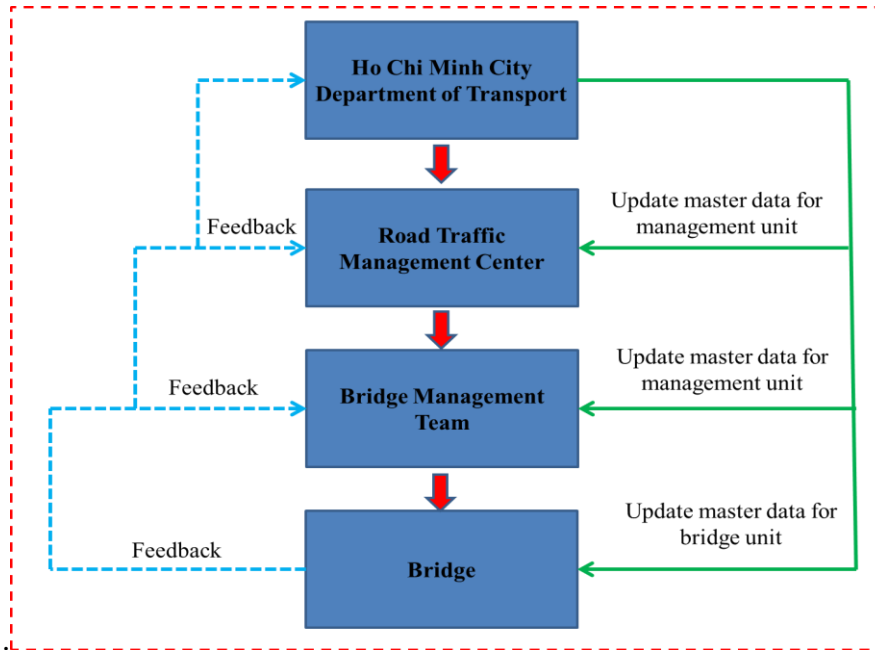


Figure 3. Hierarchy of Ho Chi Minh City Bridge Management Units.

Bridge management records from construction to regular inspection are shown in figure 4, including: bridge construction documents (design, construction, etc.); bridge inspection; and bridge periodic measurement documents (if

any). Bridge profiles are used by management units to keep track of a lot of important information about quality and how bridges are used during working hours.

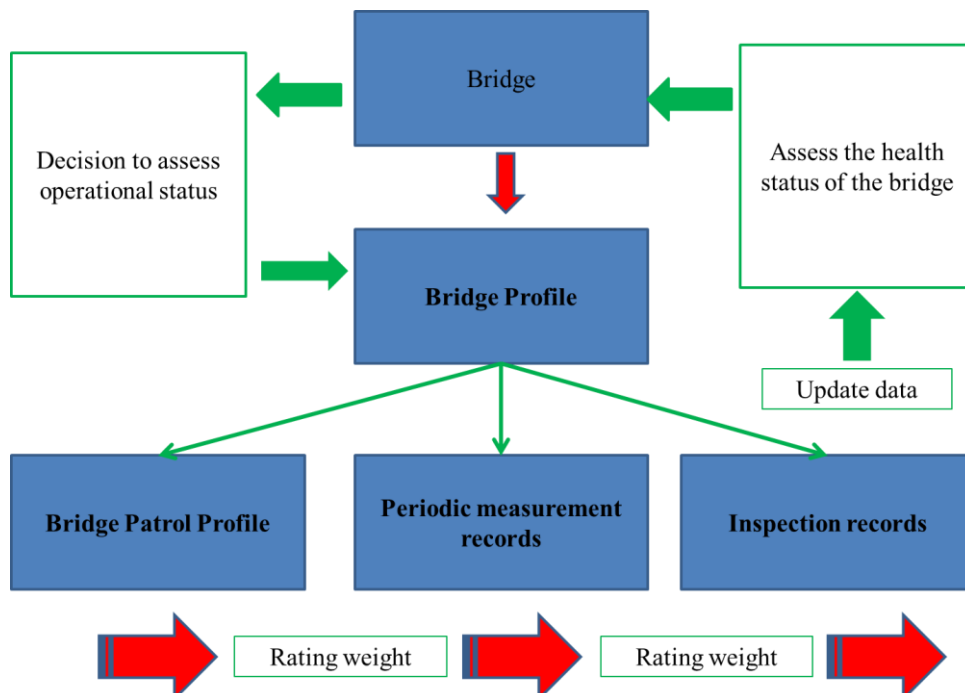


Figure 4. Typical bridge profile management model in Ho Chi Minh City.

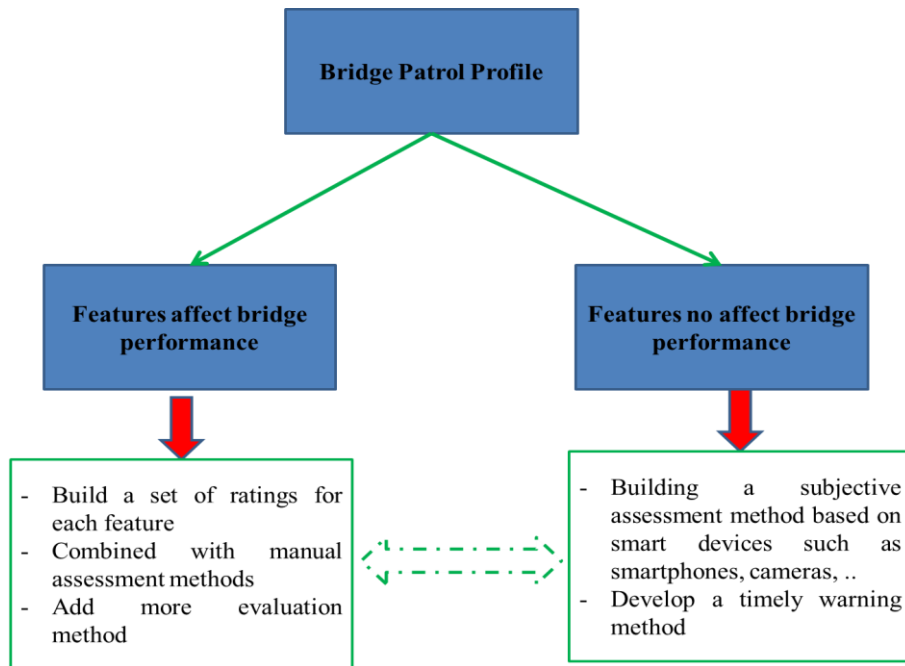


Figure 5. Influence of the characteristics of demand quality assessment in the testing process.

According to the testing process, most of the parameters are tested according to certain criteria, some of which are defined in a stereotyped and no updated manner in the context of scientific and technical developments in Fig.5.

3.1. Stereotypes in inspection standards

According to current techniques, within the scope of this study, it is possible to divide the

parameters in the current testing standards into two groups: the group of features that do not directly affect the bridge performance as shown in figure 6, and the group of those characteristics that directly affect demand as shown in figure 7. Accordingly, the study will focus on analyzing the nonconformities of the current inspection standards.

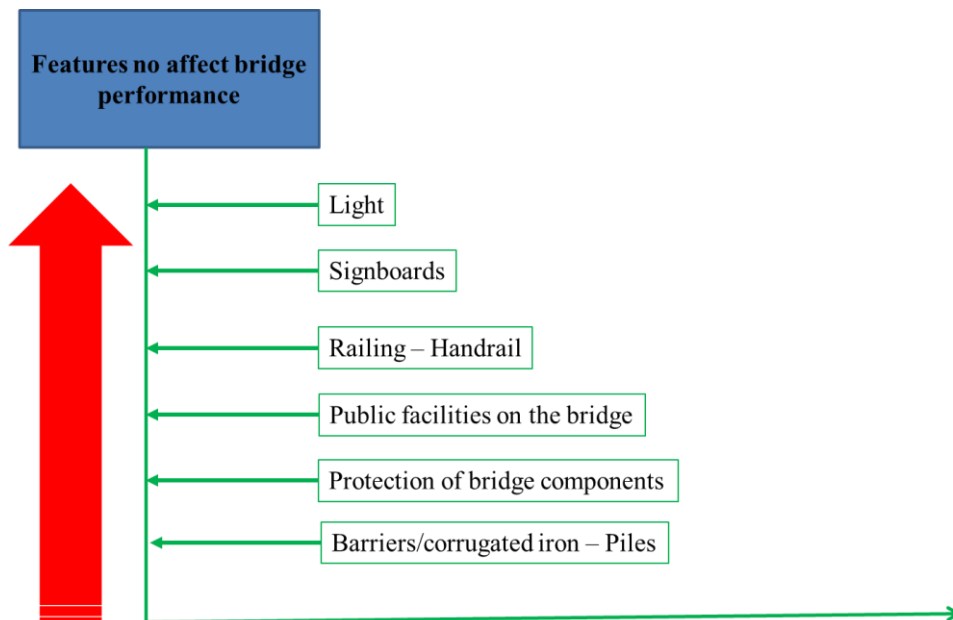


Figure 6. Features that do not directly affect bridge performance.

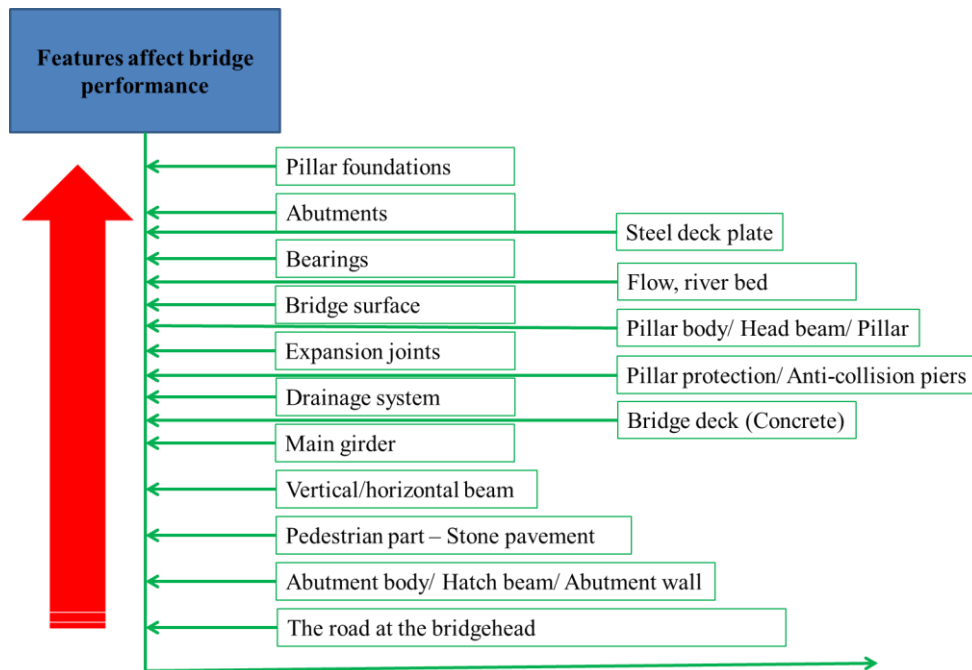


Figure 7. Features that do not directly affect bridge performance.

As analyzed before, the change in the very structure of the bridge is the main cause of damage, deterioration, or destruction. Therefore, inspection standards should only evaluate or focus on parameters that affect the structure of the bridge itself in order to have an objective and comprehensive assessment of the quality of the work at the time of progress. It is a standard inspection procedure. However, the uniform

evaluation of parameters, including those that are not related or have little to do with the influence of the work, has made the standard too complicated. This means that the cost of conducting the inspection is still too high, making it difficult for the management units to consider and choose the bridges to be tested instead of the exact regulations that the standard provides, as shown in table 1.

3.2. Evaluation of the characteristics affecting the failure process of the bridge

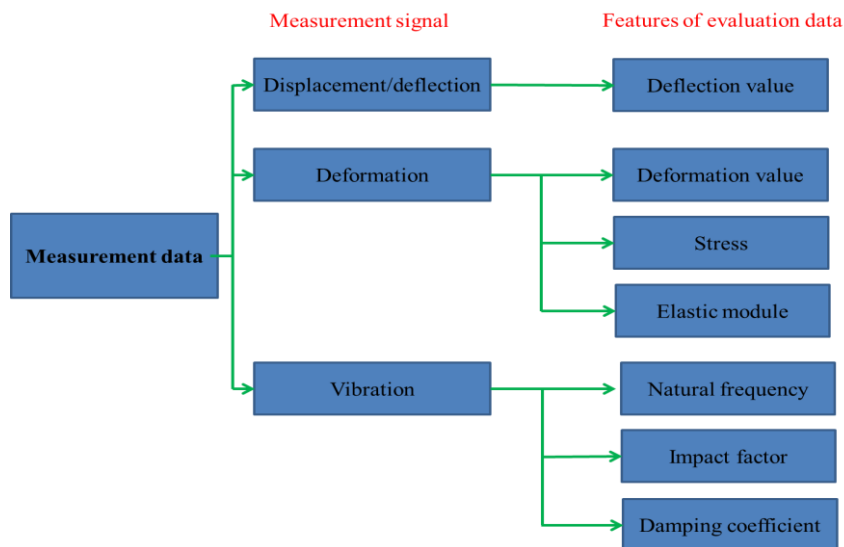


Figure 8. But the main parameter affecting the quality of the work is specified in the inspection standard.

According to the testing standard, from a mechanical point of view, the parameters that directly affect the bridge's operation are shown in

figure 8. In which, it can be divided into 3 different types of measurement signals, including: switching signal. position/deflection

signal, distortion signal, Vibration signal. From the above signal types, after the analysis process, different characteristics will be obtained to serve in the evaluation process. The study will analyze and evaluate some of the main parameters shown in the test requirements from a mechanical point of view [24,30].

3.2.1. Natural frequency

Natural frequency is one of the most commonly used parameters in bridge testing [24][30]. During the design and construction phase of a bridge, the natural frequency is always calculated so that the bridge structure must have a natural frequency greater than the forced Vibration frequencies caused by the environmental impact that the bridge has to endure when However, over a long period of use, under the effect of material

aging as well as unforeseen environmental impacts, the bridge will become more and more difficult to put into use. degrade and the natural frequency will decrease. Many of the above studies show that a classical parameter such as natural frequency is the most representative parameter for the ability to express the overall stiffness of the system through the expression $\omega \approx \sqrt{EJ_x}$, however, natural frequency is a complicated parameter, which is still lame when applied to testing standards. In which, according to the requirements of the test, the natural frequency is determined through the test load moving on the bridge according to the requirements of: load, travel speed, direction of travel and type of vehicle. Thus, the natural frequency is determined through a graph as shown in figure 9. This is a typical graph when the load is tested on the bridge.

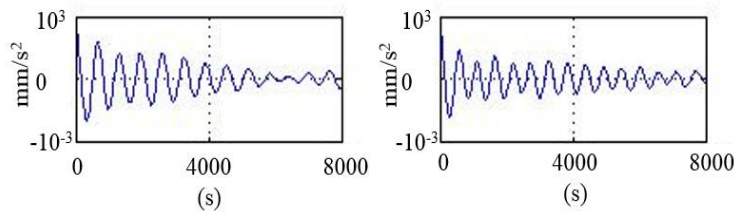


Figure 9. Vibration signal obtained from the test criterion.

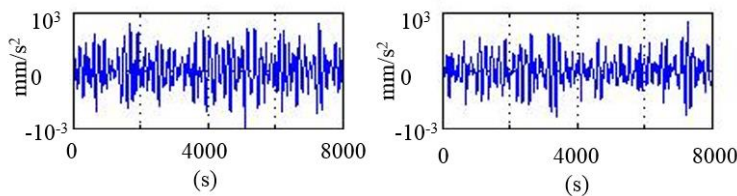


Figure 10. Actual vibration signal at bridge in the same measuring position.

However, the actual signal during the traffic on the bridge is completely different, as shown in figure 10. The cause of the difference between figure 9 and figure 10 is due to the model of traffic on the actual bridge. This is completely different from the load tested under the test. Even when combined with different analysis methods, the natural frequency value parameter does not give the desired results because of the difference in the mechanical nature of the measured signal

between the test and the actual one. figure 11 is the natural frequency value obtained from the signal segment as shown in figure 9, and figure 12 is the value of the natural frequency obtained from the signal segment as shown in figure 10. Analysis results of the actual obtained natural frequency value in different frequency forms, compared to the signal from the test that only obtains one frequency value [30].

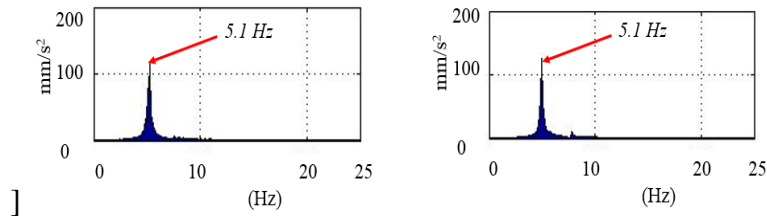


Figure 11. The natural frequency value obtained from the two signal segments in figure 9 [30].

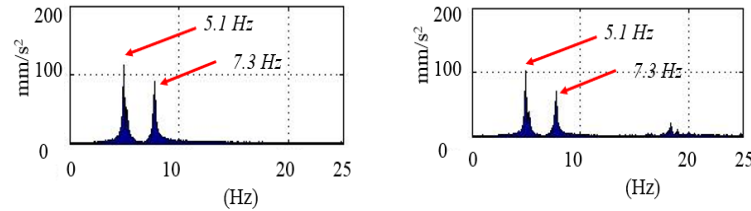


Figure 12. The natural frequency values obtained from the two signal segments in figure 10 [30].

Thus, the ability to evaluate construction quality as well as identify defects and the self-existence of defects in the structure when strictly applied according to testing standards using natural frequency parameters is still not high, and especially very difficult. It is difficult to apply this value in practice to evaluate the work because the change in this value when conducting the test is much lower than the change in stiffness on beams caused by defects.

3.2.2. Damping coefficient

The main purpose of determining the damping coefficient of the structure is to evaluate and check the overall material homogeneity of the engineering structure through measurement data. Therefore, the damping coefficient is also one of the mandatory parameters specified in the current standard. From the point of view of design and quality assessment, the tendency to use damping to assess the working condition of the bridge structure is more common because they feel that the damping coefficient is more sensitive than the natural frequency for the bridge structure with the change in stiffness at the time of testing. The defect usually exists mainly in the material, which increases the damping of the structure, which is related to the energy loss during the active structure of the structure. However, it is not always possible to determine the damping coefficient from the actual model. As we all know, in practice, it is not always possible to

determine the value of the damping coefficient because it only appears when there is a damping of the amplitude with time. To determine those value ranges, we must pay attention to their acceleration graph. figure 13 is a puzzle that helps you figure out the damping coefficient for real data that is used in the testing process.

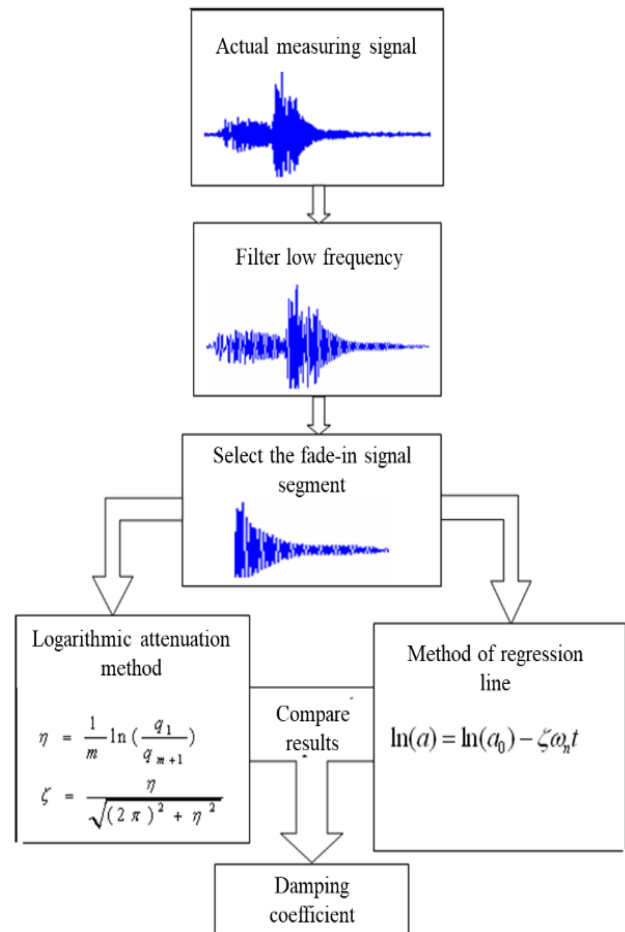


Figure 13. Procedure for determining the actual magnetic damping coefficient [24].

The characteristics of the damping coefficient value are also influenced by the material properties and the decisive spherical shape. With 3 groups of bridges surveyed individually, including: the group of pre-stressed concrete bridges in table 2, the group of steel-steel composite bridges in table 3 and the overpass group as table 4, the actual damping coefficient has certain errors. Its performance is also affected by errors in signal acquisition as well as data processing. In this case, finding the signal segment to obey the damping law also causes a

large error for this coefficient. In the actual traffic process, when the load across the bridge is not a single load but a series of different loads moving at different speeds, the force acting on the bridge span is also complicated by load measuring force, inertial force, damping force of the vehicle's spring systems, etc. Therefore, the regulation of the value of the damping coefficient for all types of bridges is not appropriate and requires a large adjustment to the standard. current inspection.

Table 2. Damping coefficients of some bridges in the group of prestressed concrete bridges over 4 measuring periods [30].

| N ₀ | Bridge (Vietnamese name) | Damping coefficient value | | | | Error% |
|----------------|-----------------------------|---------------------------|----------------------|----------------------|----------------------|--------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 1 | Cầu Cá Trê 2 | 0,0023 | 0,0025 | 0,0021 | 0,0019 | 9,091 |
| 2 | Cầu Giồng Ông Tố 1 | 0,0022 | 0,0023 | 0,0021 | 0,0024 | 4,444 |
| 3 | Cầu Chùm Chụp | 0,0097 | 0,0089 | 0,0093 | 0,01 | 3,958 |
| 4 | Cầu Làng | 0,0247 | 0,0273 | 0,0193 | 0,0148 | 20,790 |
| 5 | Cầu Tăng Long | 0,003 | 0,0028 | 0,00243 | 0,00259 | 7,209 |
| 6 | Cầu Vàm Xuông | 0,0053 | 0,0057 | 0,0046 | 0,005 | 6,796 |

Table 3. Damping coefficients of some bridges in the group of composite steel bridges over 4 measuring periods [30].

| N ₀ | Bridge (Vietnamese name) | Damping coefficient value | | | | Error% |
|----------------|-----------------------------|---------------------------|----------------------|----------------------|----------------------|--------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 1 | Đền 1 | 0,0031 | 0,0034 | 0,0032 | 0,0034 | 3,816 |
| 2 | Đền 2 | 0,0025 | 0,0024 | 0,0022 | 0,0030 | 9,406 |
| 3 | Giồng Ông Tố 2 | 0,0035 | 0,0029 | 0,0043 | 0,0030 | 13,868 |
| 4 | Giồng Ông Tố Mới | 0,0040 | 0,0043 | 0,0041 | 0,0042 | 2,409 |
| 5 | Mỹ Thủy 2 | 0,0073 | 0,0075 | 0,0069 | 0,0074 | 2,577 |
| 6 | Sài Gòn | 0,0025 | 0,0032 | 0,0027 | 0,0028 | 7,142 |
| 7 | Huyện Thanh | 0,0148 | 0,0164 | 0,0174 | 0,0146 | 6,962 |

Table 4. Damping coefficients of some bridges in the group of bridges overpassing 4 measuring times [30].

| N ₀ | Bridge (Vietnamese name) | Damping coefficient value | | | | Error % |
|----------------|-----------------------------|---------------------------|----------------------|----------------------|----------------------|---------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 1 | Cầu vượt Linh Xuân | 0,0049 | 0,0043 | 0,0048 | 0,0042 | 6,593 |
| 2 | Cầu vượt Bình Phước 1 | 0,0026 | 0,0028 | 0,0028 | 0,0027 | 2,752 |
| 3 | Cầu vượt Bình Phước 2 | 0,0022 | 0,0030 | 0,0024 | 0,0025 | 9,406 |
| 4 | Cầu vượt Sóng Thần 1 | 0,0023 | 0,0024 | 0,0026 | 0,0028 | 6,931 |
| 5 | Cầu vượt Sóng Thần 2 | 0,0024 | 0,0025 | 0,0027 | 0,0029 | 6,667 |

| N ₀ | Bridge (Vietnamese name) | Damping coefficient value | | | | Error % |
|----------------|-----------------------------|---------------------------|----------------------|----------------------|----------------------|---------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 6 | Cầu vượt Thủ Đức 1 | 0,0024 | 0,0027 | 0,0026 | 0,0028 | 4,762 |
| 7 | Cầu vượt Thủ Đức 2 | 0,0049 | 0,0050 | 0,0051 | 0,0049 | 1,508 |

3.2.3. Impact factor

Impact factor is a concept that is used in bridge testing in Vietnam and around the world. The value of the impact factor is determined by the ratio of the maximum deflection of the beam to the static deflection at the center of the beam length when the beam is subjected to impact and then vibration freely with the speed and load, causing the collision that is strictly regulated. This coefficient is evaluated through equation (1). But the equation for determining the impact factor is determined by Timosenco [28]:

$$h_{sxxk_{\max}} = 1 + \frac{v^2}{g} \frac{Pl}{3EJ} \quad (1)$$

In which: P - load of the survey object; l - length of survey object; EJ - hardness of the survey object; g - acceleration due to gravity; v - survey speed. equation (1) shows that the impact factor is a quantity that depends on both the displacement velocity v and the magnitude of the load P. The study investigates the impact factor represented by a damped signal segment of Ben Noc Bridge. This is a bridge in the group of prestressed concrete bridges located in District 9. During the monitoring period from 9/2011 to 9/2012. After 4 tests, and the first test was carried out in 9 measurements on September 21, 2011, ...to October 1, 2011, we got the results of the impact factor as shown in table 5.

Table 5. Value of stimulation coefficient calculated from different data sets of Ben Noc bridge, phase 1 of measurement on September 21, 2011, [30].

| | 1 st time | 2 nd time | 3 rd time | 4 th time | 5 th time | 6 th time | 7 th time | 8 th time | 9 th time |
|----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Static deflection (mm) | 1.39 | 1.97 | 2.30 | 2.93 | 3.74 | 3.91 | 3.82 | 3.84 | 5,14 |
| Dynamic deflection (mm) | 1.67 | 2.60 | 2.98 | 4.31 | 5.30 | 4.44 | 4.73 | 4.85 | 6,12 |
| Impact factor | 1.19 | 1,32 | 1.29 | 1.47 | 1.41 | 1.13 | 1.23 | 1,313 | 1,19 |

The results from table 5 show that, at different times, the values of the stimulation coefficient obtained are different. The reason why this factor does not converge or is fixed is the characteristic

of the load acting on this factor. Table 6 is the result of evaluating the error of the impact factor in one measurement in the 1st time on September 21, 211, according to table 5.

Table 6. Average value and error of the impact factor of Ben Noc bridge, measurement phase 1 [30].

| | 1 st time | 2 nd time | 3 rd time | 4 th time | 5 th time | 6 th time | 7 th time | 8 th time | 9 th time |
|----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Static deflection (mm) | 1.396 | 1.97 | 2.3 | 2.93 | 3.74 | 3.91 | 3.82 | 3.84 | 5,145 |
| Dynamic deflection (mm) | 1.67 | 2.6 | 2.98 | 4.31 | 5.3 | 4.44 | 4.73 | 4.85 | 6,12 |
| Impact factor | 1.195 | 1,32 | 1.29 | 1.47 | 1.417 | 1.135 | 1.237 | 1,313 | 1,19 |

Based on table 6, the study found that the coefficient of excitement has a high difference (51.29%) in the different data sets in the 1st

session. Similar to the results from other tests on 1/ 2012, 5/2012 and the last test in 8/2012 gives us the results according to table 7.

Table 7. Value of impact factor through 4 measurements at Ben Noc bridge [30].

| | The average value | | | | Error % |
|-------------------------|----------------------|----------------------|----------------------|----------------------|---------|
| | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| Static deflection (mm) | 3,22 | 3,82 | 1,98 | 2,30 | 24,37 |
| Dynamic deflection (mm) | 4,11 | 4,73 | 2,85 | 2,98 | 20,51 |
| Impact factor | 1,28 | 1,24 | 1,44 | 1,29 | 20,3 |

Similar to the damping coefficient, when surveying 7 bridges in table 8 belonging to the group of prestressed concrete bridges with different measurements, the error level of this coefficient is always relatively high, of which 6/7 bridges have a difference of more than 20% and

1/7 have a difference of less than 20%. This can be explained by the time of different measurement sessions leading to different traffic volumes (which include speed and load when crossing the bridge at the time of measurement).

Table 8. Impact factor of 7 bridges in the group of prestressed concrete bridges [30].

| N ₀ | Bridge (Vietnamese name) | Impact factor | | | | Error% |
|----------------|-----------------------------|----------------------|----------------------|----------------------|----------------------|--------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 1 | Đền 1 | 1,1743 | 1,383 | 1,037 | 1,266 | 26,098 |
| 2 | Đền 2 | 1,102 | 1,372 | 1,459 | 1,058 | 23,458 |
| 3 | Giồng Ông Tố 2 | 1,503 | 1,058 | 1,472 | 1,12 | 23,451 |
| 4 | Giồng Ông Tố Mới | 1,094 | 1,437 | 1,082 | 1,381 | 21,721 |
| 5 | Mỹ Thủy 2 | 1,384 | 1,039 | 1,192 | 1,215 | 24,832 |
| 6 | Sài Gòn | 1,031 | 1,341 | 1,102 | 1,350 | 25,411 |
| 7 | Huyện Thanh | 1,019 | 1,224 | 1,375 | 1,221 | 11,665 |

Table 9. Impact factor of 7 bridges in the group of steel girder composite concrete bridges [30].

| N ₀ | Bridge (Vietnamese name) | Impact factor | | | | Error% |
|----------------|-----------------------------|----------------------|----------------------|----------------------|----------------------|--------|
| | | 1 st time | 2 nd time | 3 rd time | 4 th time | |
| 1 | Cầu Cá Trê 2 | 1,058 | 1,398 | 1,289 | 1,102 | 16,901 |
| 2 | Cầu Giồng Ông Tố 1 | 1,083 | 1,283 | 1,435 | 1,050 | 13,420 |
| 3 | Cầu Chùm Chụp | 1,062 | 1,217 | 1,461 | 1,07 | 11,684 |
| 4 | Cầu Làng | 1,161 | 1,058 | 1,365 | 1,070 | 9,067 |
| 5 | Cầu Tăng Long | 1,380 | 1,063 | 1,219 | 1,327 | 14,772 |
| 6 | Cầu Vàm Xuông | 1,467 | 1,036 | 1,136 | 1,364 | 17,290 |

Similar to the group of prestressed concrete bridges, the survey study of the group of steel beam composite concrete bridges also obtained similar results when the shock coefficient still had too many errors in the determination process as shown in table 9. At the same time, corresponding to different demand groups, this coefficient will have different responses. So, the

standard still doesn't set a single limit for all demand groups.

4. Conclusion and development orientation

By analyzing and evaluating the outstanding problems in the processes of data collection, processing, and quality assessment of the work based on the parameters obtained during the

verification process, we have shown the following: Some that are being assessed and surveyed are still not suitable with the current inspection requirements at the request of the state and specifically applied in HCMC. While the verification process is to determine the parameters that are directly related to the quality of the work, such as: frequency, amplitude of vibration, shock coefficient, damping coefficient, etc., to do the work. For this inspection, the management agencies also need to expend a lot of effort as well as the high cost of one-time implementation. However, the measurement in accordance with the requirements of the standard still has many problems. The conclusions from this study are presented as follows:

(i) Among the parameters tested, they are divided into 2 groups: the group that does not directly affect the quality of the work and the group that directly affects the quality of the work. Since then, for each group, the standard needs to have separate evaluations to avoid equating the current criteria.

(ii) For the criteria directly related to the quality of the works, the process of evaluating, commenting, collecting, and processing data still follows a path that is quite stereotypical. The study has investigated a number of relevant prominent parameters, including: natural frequency value, damping coefficient, shock coefficient, etc., but the evaluation related to this coefficient is still inadequate because:

- The measurement method from testing, as well as the actual behavior of the aggregates when working in real-world conditions, are still a long way off. When most of the measurements from the test standard are too simple, they are usually done by single load condition, conventional load, or predicted load, whereas the actual traffic condition has live load. It is very complex, including many operating states, many velocities, many modes of traffic, and frequent overloading. Because of this, the standard has not

been able to update these parameters accurately and appropriately;

- The assessment process of the inspection is still stereotyped. The analysis of parameters such as damping coefficient, shock coefficient, and natural frequency value shows very large differences between the test results and the actual measurement results. Moreover, these parameters depend on each bridge group, each bridge type, and the material of the bridge structure.

In the next publications, the research will address issues such as: necessary additions to the bridge testing process based on the development of science and technology; the bridge health monitoring system has been bringing about important decisions in assessing the quality of bridge work; the existing demand testing process – how to better match the current rate of change.

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