Special Aspects of Steel Bridge Structure

Himanshu Borkar

March 28, 2022

Special Aspects of Steel Bridge Structures

Abstract

Every nation needs the infrastructure to perform all kind of activities related to the improvement and service of the society. Transportation system became part of the infrastructure due its connection between two destinations, using maritime, land, or aerial methods, creating a link for social and economic activity. Bridges are widely used to cross rivers, valleys, and roads, providing a passage with other parts of the land since ancient times to modernity. Each structure has different requirements to cover, such span clearage, traffic flow, geometry and characteristics of the place to build; therefore, a great variety of bridges can be developed. Common materials used on construction are structural steel, reinforced concrete, pre-stressed concrete, or post-tensioned concrete; depending on the structural behavior of each type of bridge, there will be a maximum clear span to cover, which depends directly on the project's budget. There are a variety of loads and environmental conditions that the new and existing structure needs to support effectively, including dead load, traffic, rain, wind, flood, and seismic events, using effective structural design process and techniques; on the other hand, there are long-term deterioration process, such as corrosion, wear, and fatigue, which should be considered on the maintenance process, avoiding additional costs, several damages, and catastrophic failures. Prevention and control of degradation process is achieved by effective maintenance methods applying protection technology such as paints, coating and cathodic protection. The purpose of this chapter is to show a brief review of ancient and modern bridges, including the process of design.

1. Introduction

If a society wants all its function working efficiently, it requires many elements that meet its needs. Basic functions such as food, water, electricity and transportation require all types of structures to fulfill its purpose. Infrastructure embraces all the buildings that support the goods and services of the community, with an integral and optimal functioning.

All the services of the society require some type of support to be carried out. An engineer, architect or lawyer needs a space to develop their businesses and support its clients; a merchant needs a highway to transport their products to their final destination; supplying water to any destination requires pipes, pipelines and tanks. There are many examples where each service requires some type of infrastructure.

As a general example, consider the construction of an international airport. The main purpose is the aerial communication of the city, which can be used for traveling, tourism and transportation of goods. Listing all the needs of any airplane, there will be at least the following requirements to fulfill:

Landing strip to perform effectively the air traveling.

Control tower for monitoring the air traffic flow.

Airport building to perform all administrative activities.

Hangar for airplane maintenance and storage purposes.

Water supply, storage, pipelines and sewage for the entire place.

Fuel supply and storage for the airplanes.

Land highways and bridges to connect the city with the airport.

Electricity towers and electrical station to supply energy.

According the previous example, there are many construction elements and buildings that enhance the aerial communication. The combinations of these structures contribute with the airport to operate efficiently. This type of infrastructure can contribute enabling tourism, transportation, productivity and employment opportunities, increasing the economic activity. Therefore, the infrastructure has a wide variety of structures which can be part of a specific sector and fulfill a simple function.

If any infrastructure element of the airport fails, there will be issues with its functionality; for example, if any bridge is closed due any malfunction or maintenance, the transport of the passengers, goods and services will be affected.

Bridges have a special place in transportation infrastructure due its direct relationship with other places. These structures have the purpose to carry on the traffic loads of the highway, crossing any obstacle and perform an effective communication between two destinations. Since there are many variables to consider in the performance of the bridges, such geometry, span clearance, traffic flow and available materials, there are many options of bridges to choose.

Planning, design and construction process for any bridge looks logical and necessary steps, looking for the good behaviour of the structure during any traffic load or resisting flood or seismic events. However, maintenance process guarantee the life of the structure, which applied correctly, will avoid any closure of the bridge and traffic issues.

2.Literature Review

Bridges are one of the most important structural typologies made by civil engineers and have a great impact on society by favoring territorial connection. The design of bridges must integrate different requirements to reach a design according to the required needs. In addition, the design of bridges must consider the context in which the structure is framed. This context is related to the characteristics of the place where the structure will be located and the determining factors from economic, cultural, and environmental point of views.

Engineers are faced with making designs that must take into account factors that go beyond the simple fact that their work fulfils the function for which it is designed [1]. In bridge design, other aspects, such as the construction process or the structure's reuse or demolition strategies, must be evaluated. This requires a clear understanding of the behavior and stresses that their materials will be subjected to throughout their service life [1]. In addition, these infrastructures have an associated environmental impact during their construction [2] that must also be considered. This impact can be mitigated with good design and planning [3]. Since the World Commission of Environment and Development defined sustainable development guidelines [4], national policies have focused on obtaining infrastructures that accomplish the sustainable development terms. In addition, the United Nations defined the Sustainable Development Goals [5] as objectives for 2030. Because of this, it can be understood that one of the demands of society is the incorporation of sustainability in infrastructure design. De Jong [6] adds environmental friendliness as one of their design principles. Furthermore, innovation in building materials and structural shapes give designers more tools to make designs more in line with current design criteria. In Figure 1, the scheme of design criteria have been displayed.

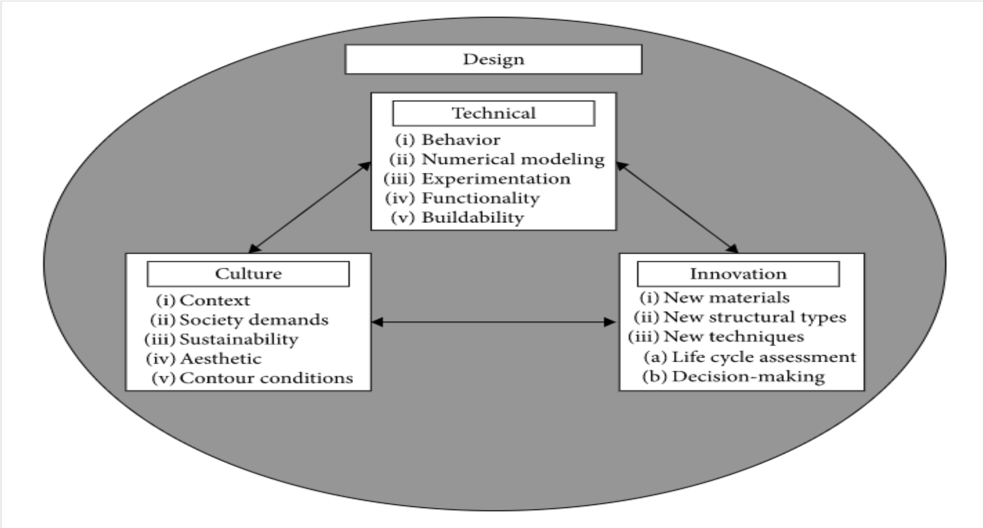

Figure 1

To achieve the objectives of the current design, steel-concrete composite bridges (SCCBs) can be a good alternative due to the recyclability of the steel parts of the structure [7]. SCCBs have been used extensively since the 20th century, when composite structure theories were developed more generally [8]. In addition, Musa and Diaz state that this type of bridge is highly efficient due to the possibility of placing the steel and concrete in the parts of the cross section where they perform best. They also provide added value due to their attractive appearance [9].

The aim of this review is to collect knowledge regarding SCCBs to identify the approach that designers and researchers have given to design. This work provides designers and technicians with a guide where current information is collected regarding the behavior of this type of structure, the methods used by authors to reach the optimum design, the construction methods and maintenance, as well as the repair strategies. Furthermore, a lack of knowledge related to SCCBs is found, offering researchers the possibility of focusing their efforts on the weakest areas. The gaps are obtained by using statistical techniques that analyze the correlation between different variables. Furthermore, all the information considered in this study gives a broader vision of the possibilities of the sustainable design of SCCBs, considering sustainability in the whole process.

3.Advantages of Steel bridge structure

The multiple advantages of steel equate to a more cost-effective option than other building materials. Smaller crews working with smaller scale construction equipment can install and erect steel-based projects because of its light weight. This lighter weight also allows for faster installation, so projects are erected more quickly. This timeliness also affords key cost-savings advantages to construction companies. Some of its advantages are-

- Lower construction costs compared with other materials helps save money for municipal governments. Faster construction reduces traffic and business disruption.
- Steel bridges last longer than other types, which means they don't have to be replaced as quickly. Steel components require less maintenance and don't need to be replaced as often.
- Steel is highly adaptable to different climates and geographic conditions. The relative lightness of steel compared with other materials reduces energy use during delivery and construction.
- Steel components are less likely to be damaged during extreme events like hurricanes and earthquakes. Steel components are used to transmit critical utility services across bridges.
- Steel has a remarkably high strength-to-weight ratio. This minimizes the weight of bridge superstructures, which reduces the cost of building the substructures that support them.
- One of the biggest advantages of steel is weight savings, which means lower erection costs, since the bridge pieces can be handled with lighter equipment. In addition, for the same span and load, a steel girder requires less depth than a concrete girder, which can be helpful when constrained by vertical clearance requirements.
- Generally, it's easier to make spans continuous for both live and dead loads and to develop composite action with steel designs rather than with concrete ones.
- It's easier to inspect and determine the structural state of a steel bridge where all the components are visible. The long-term durability and cost effectiveness of steel bridges will be further enhanced by the use of high performance steels with weathering capabilities.
- Steel permits cost-effective longer spans for crossing streams, lakes, wetlands, and environmentally protected areas. The long spans may eliminate or at least minimize environmental impact.

4.Elements and components of steel bridge

The structural steel for steel bridges should be selected according to the required material properties or the stress state where used, environmental conditions at the construction site, corrosion protection method, construction method, etc. The physical properties of structural steel such as strength, ductility, toughness, weldability, weather resistance, chemical composition, shape, size, and surface characteristics are important factors for designing and construction of steel bridges. Discussed below are elements and components of steel bridge.

5.Theory of bridge evaluation and reinforcement

There are six primary factors affecting the safe and reasonable use of existing bridge structures. First is the aging of bridges. Compared with the general design life of bridges in China (50 or 100 years for highway bridge, and 100 years for railway bridge), a lot of bridges have entered their aging period and show the problem of insufficient durability. Second, the threatening of increasing traffic volume makes the bridge safety problem more and more prominent. Third is that the common overload phenomenon aggravates the damage and brings potential safety hazards for bridge structures. Fourth is that a large number of bridges are 'working with defects', and the number of bridges with insufficient bearing capacity or dangerous bridges is increasing year by year. Fifth is that all kinds of natural disasters and man-made accidents threatens the normal use of bridges. Sixth, the upgrading and reforming of modern transportation system put forward new requirements for the long-term use of existing bridges. The research on the theory and technology of bridge's structural evaluation, reinforcement and maintenance associated with above six factors is one of the hottest academic subjects at home and abroad, which has important theoretical researching prospect and practical value.

6.Bridge model tests and new testing techniques

With the continuous development of new materials and new technologies in bridge design, the mechanical characteristics and durability of critical parts of the bridge structure deserve attention. Compared with the original bridge test, the model test has the advantages of easier control of parameters, less restriction of environmental conditions, more economical, stronger pertinence, etc. It plays an irreplaceable role in the development of bridge engineering.

Static test

Static tests have been widely used in the mechanical behavior research of bridge components and their results are very rich. For example, in the static test research of the main beam, Wang et al. (2019m) designed and made three scaled models (1:4) of corrugated steel web composite beam considering shear span ratio in order to explore whether corrugated steel plate can replace flat steel plate as beam web of transverse beam in the suspension bridge tower. In the research of the anchorage zone of cable-stayed bridge pylon, Xiao et al. (2019a) studied the load transfer mechanism of the steel-concrete composite pylon anchorage zone of the cable-stayed bridge structure through the static full-scale model test and numerical simulation. To sum up, it can be seen that the static model test research mainly focuses on exploring the force transmission mechanism of the structure, design optimization, and verifying the safety and reliability of the actual structural design.

Fatigue test

Fatigue damage is one of the main failure modes of bridge structures, especially the bridge deck system components of steel structures which are affected by the service environment, material deterioration, structural details, etc. Due to the direct bearing of wheel loads, the bridge deck system structures often suffer from pavement damage, plate cracking and other conditions that affect the driving comfort and safety. At present, the fatigue test is one of the main means to study and verify the fatigue performance of structures and materials. Shi et al. (2019b, c) designed and manufactured a full-scale orthotropic bridge deck fatigue test model, which contains two U-ribs and two V-ribs in order to study the fatigue performance of the fatigue sensitive area at the joint of stiffening ribs and diaphragms of railway orthotropic steel bridge deck. Yuan et al. (2019c) carried out fatigue cyclic loading on a complete model to produce cracks, then repaired the cracks and poured UHPC cover on the roof.

In addition to steel structure fatigue, concrete structures also crack under long-term repeated fatigue loads. Lv et al. (2020) studied the effect of rubber particles on the uniaxial compressive fatigue performance of self-compacting rubber lightweight aggregate concrete (SCRLC) through uniaxial compressive tests.

Shaking table test

Shaking table test is one of the most widely used test methods in seismic research at present. Scholars have carried out a large number of shaking table tests from the perspectives of the bridge structure, construction methods, and seismic excitation modes.

Shao et al. (2019) carried out the shaking table test on a large scale simply supported beam bridge, with the consideration of more realistic seismic response and smaller impact of the dimension effect, to study the seismic performance of single-column piers. The El Centro N-S longitudinal and vertical seismic waves were simulated using a 3-way 6-degree-of-freedom large-scale seismic shaking table. Sun and Xie (2019), Xie and Sun (2019) made a 1/70 super-long cable-stayed bridge model to study the seismic performance of pile-soil-bridge. Zou et al. (2019b) proposed a new isolation system for the functional separation of high-speed railway bridges, which was verified by shaking table tests. In order to study the seismic response of high-speed railway continuous girder bridges built in our country, Jiang et al. (2019a) made a 1/12 scaled typical high-speed railway continuous girder bridge specimen in China, and detailedly introduced the shaking table test process. When studying the seismic performance of the long-span pile foundation cable-stayed bridge, Sun and Xie (2019) conducted a 1/70 full-bridge model shaking table test study on a super-long span cable-stayed bridge. Zheng et al. (2019c) conducted shaking table tests on four and a half proportion of geosynthetic reinforced soil (GRS) abutment specimens.

To study the seismic performance and isolation effect of the traditional friction swing bearing (FPB) and the new three friction swing bearing (TFPB) isolation bridge, Wen et al. (2019a) conducted shaking table tests on the 1/10 scaled FPB and TFPB simply supported beam bridge models under the excitation of a two-direction earthquake. Brito et al. (2019) evaluated the seismic performance of a new type of reinforced concrete bridge pier with a low cost sliding pendulum system through a one-way shaking table test. Zhou et al. (2019f) conducted shaking table tests on a 1/10 scaled single span bridge, and studied the seismic response and shaking isolation effect of the bridge with a post-tensioned swing pier with negative swing stiffness.

Hybrid testing

Structural hybrid test, also known as the pseudo-dynamic test, is a new seismic test method which combines numerical simulation with a physical test. The hybrid test divides the whole structure into two parts. One is the test substructure, and the other is the numerical substructure, which is used in the computational simulation. This method can solve the problem that the actual structure sometimes is too large or too heavy that exceeds the loading capacity of the test equipment. Since the hybrid test technology was put forward in 1992 (Guo et al. 2019b), it has been widely used in the research of the seismic performance of building structures, and then gradually used in the research of the seismic performance of bridge structures. Yuan et al. (2019a) carried out pseudo-dynamic tests on the scaled model of concrete-filled steel tubular lattice column piers of the Ganhaizi super large bridge and studied the seismic performance of such structures under different intensity earthquakes and main aftershocks. To study the seismic performance of the tall-pier bridge with thin-walled hollow sections of the rigid frame, Zhu et al. (2019c) proposed a novel hybrid simulation method for on-line updating of the concrete constitutive parameters (UHS).

New testing technology

With the rapid development of various digital, automatic and intelligent modern equipment and instruments, new testing technologies continue to emerge. These new technologies could obviously improve the efficiency and quality of model testing (including detection and acquisition of stress state, micro deformation, microcracking and damage of steel and concrete materials, etc.). According to the test purpose, it can be roughly divided into the following categories: 1) stress and strain; 2) geometric displacement; 3) vibration acceleration; 4) detection of concrete cracks and internal defects; 5) detection of metal cracks; 6) detection of material damage.

In stress-strain measurement, the optical fiber method is widely used in structural strain monitoring because of its high accuracy and good economy (Ye et al. 2020). In addition, digital image correlation technology can also be applied to strain testing. Guo et al. (2019b) used the technology of strain measurement and digital image correlation (DIC) to determine the deformation of samples when testing the tensile properties of high-strength concrete with different compressive strength.

Geometric displacement is often used in the experiment. Displacement meter, laser scanning technology, and optical fiber method are widely used in displacement measurement. Ghaffar et al. (2019) proposed a design method of two-dimensional displacement sensor based on the coupling effect of macroscopic bending loss and optical power. With the continuous development of new materials and new technologies in bridge design, the mechanical characteristics and durability of critical parts of the bridge structure deserve attention. Compared with the original bridge test, the model test has the advantages of easier control of parameters, less restriction of environmental conditions, more economical, stronger pertinence, etc. It plays an irreplaceable role in the development of bridge engineering.

Static test

Static tests have been widely used in the mechanical behavior research of bridge components and their results are very rich. For example, in the static test research of the main beam, Wang et al. (2019m) designed and made three scaled models (1:4) of corrugated steel web composite beam considering shear span ratio in order to explore whether corrugated steel plate can replace flat steel plate as beam web of transverse beam in the suspension bridge tower. In the research of the anchorage zone of cable-stayed bridge pylon, Xiao et al. (2019a) studied the load transfer mechanism of the steel-concrete composite pylon anchorage zone of the cable-stayed bridge structure through the static full-scale model test and numerical simulation. To sum up, it can be seen that the static model test research mainly focuses on exploring the force transmission mechanism of the structure, design optimization, and verifying the safety and reliability of the actual structural design.

Fatigue test

Fatigue damage is one of the main failure modes of bridge structures, especially the bridge deck system components of steel structures which are affected by the service environment, material deterioration, structural details, etc. Due to the direct bearing of wheel loads, the bridge deck system structures often suffer from pavement damage, plate cracking and other conditions that affect the driving comfort and safety. At present, the fatigue test is one of the main means to study and verify the fatigue performance of structures and materials. Shi et al. (2019b, c) designed and manufactured a full-scale orthotropic bridge deck fatigue test model, which contains two U-ribs and two V-ribs in order to study the fatigue performance of the fatigue sensitive area at the joint of stiffening ribs and diaphragms of railway orthotropic steel bridge deck. Yuan et al. (2019c) carried out fatigue cyclic loading on a complete model to produce cracks, then repaired the cracks and poured UHPC cover on the roof.

In addition to steel structure fatigue, concrete structures also crack under long-term repeated fatigue loads. Lv et al. (2020) studied the effect of rubber particles on the uniaxial compressive fatigue performance of self-compacting rubber lightweight aggregate concrete (SCRLC) through uniaxial compressive tests.

Shaking table test

Shaking table test is one of the most widely used test methods in seismic research at present. Scholars have carried out a large number of shaking table tests from the perspectives of the bridge structure, construction methods, and seismic excitation modes.

Shao et al. (2019) carried out the shaking table test on a large scale simply supported beam bridge, with the consideration of more realistic seismic response and smaller impact of the dimension effect, to study the seismic performance of single-column piers. The El Centro N-S longitudinal and vertical seismic waves were simulated using a 3-way 6-degree-of-freedom large-scale seismic shaking table. Sun and Xie (2019), Xie and Sun (2019) made a 1/70 super-long cable-stayed bridge model to study the seismic performance of pile-soil-bridge. Zou et al. (2019b) proposed a new isolation system for the functional separation of high-speed railway bridges, which was verified by shaking table tests. In order to study the seismic response of high-speed railway continuous girder bridges built in our country, Jiang et al. (2019a) made a 1/12 scaled typical high-speed railway continuous girder bridge specimen in China, and detailedly introduced the shaking table test process. When studying the seismic performance of the long-span pile foundation cable-stayed bridge, Sun and Xie (2019) conducted a 1/70 full-bridge model shaking table test study on a super-long span cable-stayed bridge. Zheng et al. (2019c) conducted shaking table tests on four and a half proportion of geosynthetic reinforced soil (GRS) abutment specimens.

To study the seismic performance and isolation effect of the traditional friction swing bearing (FPB) and the new three friction swing bearing (TFPB) isolation bridge, Wen et al. (2019a) conducted shaking table tests on the 1/10 scaled FPB and TFPB simply supported beam bridge models under the excitation of a two-direction earthquake. Brito et al. (2019) evaluated the seismic performance of a new type of reinforced concrete bridge pier with a low cost sliding pendulum system through a one-way shaking table test. Zhou et al. (2019f) conducted shaking table tests on a 1/10 scaled single span bridge, and studied the seismic response and shaking isolation effect of the bridge with a post-tensioned swing pier with negative swing stiffness.

Hybrid testing

Structural hybrid test, also known as the pseudo-dynamic test, is a new seismic test method which combines numerical simulation with a physical test. The hybrid test divides the whole structure into two parts. One is the test substructure, and the other is the numerical substructure, which is used in the computational simulation. This method can solve the problem that the actual structure sometimes is too large or too heavy that exceeds the loading capacity of the test equipment. Since the hybrid test technology was put forward in 1992 (Guo et al. 2019b), it has been widely used in the research of the seismic performance of building structures, and then gradually used in the research of the seismic performance of bridge structures. Yuan et al. (2019a) carried out pseudo-dynamic tests on the scaled model of concrete-filled steel tubular lattice column piers of the Ganhaizi super large bridge and studied the seismic performance of such structures under different intensity earthquakes and main aftershocks. To study the seismic performance of the tall-pier bridge with thin-walled hollow sections of the rigid frame, Zhu et al. (2019c) proposed a novel hybrid simulation method for on-line updating of the concrete constitutive parameters (UHS).

New testing technology

With the rapid development of various digital, automatic and intelligent modern equipment and instruments, new testing technologies continue to emerge. These new technologies could obviously improve the efficiency and quality of model testing (including detection and acquisition of stress state, micro deformation, microcracking and damage of steel and concrete materials, etc.). According to the test purpose, it can be roughly divided into the following categories: 1) stress and strain; 2) geometric displacement; 3) vibration acceleration; 4) detection of concrete cracks and internal defects; 5) detection of metal cracks; 6) detection of material damage.

In stress-strain measurement, the optical fiber method is widely used in structural strain monitoring because of its high accuracy and good economy (Ye et al. 2020). In addition, digital image correlation technology can also be applied to strain testing. Guo et al. (2019b) used the technology of strain measurement and digital image correlation (DIC) to determine the deformation of samples when testing the tensile properties of high-strength concrete with different compressive strength.

Geometric displacement is often used in the experiment. Displacement meter, laser scanning technology, and optical fiber method are widely used in displacement measurement. Ghaffar et al. (2019) proposed a design method of two-dimensional displacement sensor based on the coupling effect of macroscopic bending loss and optical power.

As a mature technology, accelerometers are widely used in structural vibration acceleration tests. Zhang et al. (2019e) modified the existing accelerometer with silicon on insulator technology and developed a capacitive accelerometer for the structural seismic response test, which effectively improved the test sensitivity. Besides, the vibration acceleration measurement technology based on vision is popular too.

Ultrasonic and radiation methods are the latest methods to detect cracks and internal defects in concrete model structures. Carreras et al. (2019) recorded the load-displacement curve and crack front geometry of composite materials by means of X-ray photography.

Infrared, metal magnetic memory, acoustic emission and eddy current are often used in metal crack detection. Sun and Zhen (2019) proposed a method of using active infrared thermal imaging technology to detect the coating of bridge steel structure, which is more able to detect and enlarge the invisible defects of the naked eye. During the quasi-static test of Q235 portal frame, Su et al. (2019b) studied the changing characteristics of the metal magnetic signal in different stress stages. They established the corresponding relationship between the magnetic signal and its gradient value and the stress concentration position.

Scanning electron microscopy is often used to observe the failure interface of materials. Ghassemi and Toufigh (2020) studied the change of the microstructure of epoxy polymer concrete after 1 year's exposure to SEM. Zhou et al. (2019b) proposed a new corrosion detection technology of galvanized steel strand cable based on metal magnetic memory technology. This method successfully solves the problem that conventional technology is difficult to detect the internal corrosion of galvanized steel strand cable.

As for the future research of bridge model test and testing technology, more attention should be to the following aspects: to develop and construct the test equipment for multi-directional and complex static and dynamic loading equipment and large scale salt spray test chamber etc.; to develop new type of test sensor with high precision, such as distributed grating sensor, multi-point laser displacement meter, distributed crack sensor, crack image recognition sensor, introduction of medical, aerospace testing methods and 5G technology into the bridge test and transmission of testing and monitoring data; to develop test data processing and error separation technology, so as to improve the analysis accuracy of the test results.

As a mature technology, accelerometers are widely used in structural vibration acceleration tests. Zhang et al. (2019e) modified the existing accelerometer with silicon on insulator technology and developed a capacitive accelerometer for the structural seismic response test, which effectively improved the test sensitivity. Besides, the vibration acceleration measurement technology based on vision is popular too.

Ultrasonic and radiation methods are the latest methods to detect cracks and internal defects in concrete model structures. Carreras et al. (2019) recorded the load-displacement curve and crack front geometry of composite materials by means of X-ray photography.

Infrared, metal magnetic memory, acoustic emission and eddy current are often used in metal crack detection. Sun and Zhen (2019) proposed a method of using active infrared thermal imaging technology to detect the coating of bridge steel structure, which is more

able to detect and enlarge the invisible defects of the naked eye. During the quasi-static test of Q235 portal frame, Su et al. (2019b) studied the changing characteristics of the metal magnetic signal in different stress stages. They established the corresponding relationship between the magnetic signal and its gradient value and the stress concentration position.

Scanning electron microscopy is often used to observe the failure interface of materials. Ghassemi and Toufigh (2020) studied the change of the microstructure of epoxy polymer concrete after 1 year's exposure to SEM. Zhou et al. (2019b) proposed a new corrosion detection technology of galvanized steel strand cable based on metal magnetic memory technology. This method successfully solves the problem that conventional technology is difficult to detect the internal corrosion of galvanized steel strand cable.

As for the future research of bridge model test and testing technology, more attention should be to the following aspects: to develop and construct the test equipment for multi-directional and complex static and dynamic loading equipment and large scale salt spray test chamber etc.; to develop new type of test sensor with high precision, such as distributed grating sensor, multi-point laser displacement meter, distributed crack sensor, crack image recognition sensor, introduction of medical, aerospace testing methods and 5G technology into the bridge test and transmission of testing and monitoring data; to develop test data processing and error separation technology, so as to improve the analysis accuracy of the test results.

7.Conclusions

The paper reviews some advances in bridge engineering in 2019, including concrete bridges and the high-performance materials, the latest research on steel-concrete composite girders, advances in box girder and cable-supported bridge analysis theories, advance in steel bridges, the theory of bridge evaluation and reinforcement, bridge model tests and new testing techniques, steel bridge fatigue, wind resistance of bridges, vehicle-bridge interactions, progress in seismic design of bridges, bridge hydrodynamics, bridge informatization and intelligent bridge and prefabricated concrete bridge structures. With the development of bridge science and technology and the needs of national development and construction, we hope that this review article can promote bridge workers get a more comprehensive understanding of the latest progress in the bridge industry.

8.References

[1] RAPATTONI F., EASTWOOD D. BENNETT M. & CHEUNG H. Composite Steel Bridges - Concepts and Design charts, BHP Steel, 1998

[2] SZOKOLIK A. & RAPATTONI F. Coatings Guide for New Steel Bridges, BHP Steel, 1998

[3] VicRoads PBE Technical Note 99/001 – VicRoads 1998

[4] RAPATTONI F. & WELLS J.B. “New developments in bridge superstructures”, Proceedings of the AUSTROADS 1994 Bridges Conference, Melbourne, Feb 1994. [6] RAPATTONI F. & NECHVOGLOD, V. “Bridging Uncertainty with Upgradeable Steel Bridges” Proceedings of the AUSTROADS 4th Bridge Engineering Conference, Adelaide, Dec 2000.