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“Technical Research and Development for Road Policy Quality Improvement”
Study Summary

No.	Title	Principal Researcher
No. 26-5	Development of High Performance Cast Iron Bridge Deck	Kyushu Institute of Technology Professor Eiki Yamaguchi

To contribute to the project for replacing old highway bridge decks, a bridge deck which is light and good at fatigue resistance is to be developed. To be specific, spheroidal graphite cast iron whose mechanical property is similar to that of structural steel is applied to the bridge deck. The spheroidal graphite cast iron bridge deck is designed and actually produced. Its strength and fatigue resistance are tested. The possibility of employing it for a real bridge is thus explored and confirmed.

1. Backgrounds and Objects

Japanese bridges are deteriorating due to old age. Many of bridge decks have been made of reinforced concrete (RC), and they particularly suffer from deterioration. The seismic resistance of piers and foundations of old bridges is not necessarily insufficient in old bridges. The replacement of an RC bridge deck with an orthotropic steel deck would enhance the seismic resistance since the latter is much lighter than the former. However, the orthotropic steel deck is susceptible to fatigue cracks. The fatigue cracks are initiated exclusively in the weld.

If a bridge deck which is light and has good fatigue resistance is available, the replacement of an old bridge deck could improve seismic resistance without causing fatigue cracks.

Herein it is proposed that spheroidal graphite cast iron is applied to the bridge deck. The material has mechanical property similar to structural steel. The shape of a cast iron product can be very complicated without resorting to welding. Sharp edges is easily avoided, which can mitigate stress concentration. This feature helps reduce the possibility of fatigue-crack initiation as well.

Taking advantage of the features of the cast iron, the present research aims at the development of a bridge deck that has good fatigue resistance, enhances the seismic resistance of the bridge and yet economically competitive.

2. Activities in Research Period

① Trial design and cost evaluation
② Trial product of full-scale spheroidal graphite cast iron bridge deck
③ Mechanical property and fatigue strength of the material taken from the trial bridge deck product
④ Structural property of the trial bridge deck product
⑤Optimum shape of cast iron bridge deck
⑥ Design and performance verification of the connection
⑦ Selection of the best cast-iron material and establishment of casting process for mass production
⑧ Quality control items and inspection method
⑨ Verification of applicability of cast iron bridge deck

3. Study Results

- A cast iron bridge deck was designed by the finite element method. The weight per area wss 2.45 kN/m^2, confirming that it was lighter than the RC bridge deck. A bridge deck panel thus designed was actually produced. (Fig. 1)
- Taking specimens from various positions in the trial bridge deck, tensile strength, elongation and hardness were evaluated. Variations between the specimens were sufficiently small.
- The trial bridge deck was loaded statically. Plastic deformation took place only after 287 kN, which was more than twice as big as the T-load. The loading was continued until 941kN, 9 times as large as the T-load. No damage such crack was observed. Good durability has been thus proved.
- The fatigue test was conducted. The load was applied repeatedly at the panel centert. The maximum load was controlled to make the maximum stress induced in the deck equal to the allowable stress. The test was continued until the number of loading cycles reached 10 million. Stress and displacement were all stable until the end. No damage such as crack was observed. The cast iron deck has been proved to have satisfactory fatigue resistance. (Fig. 2)

・The bridge deck panels were connected to form a bridge deck. The connections were friction-type joints by high strength bolts. The wheel moving load test was then conducted: the span between main girders was 3,000 mm, the moving distance of the wheel load was 4,600 mm and the wheel load was 157 kN. The wheel moved 2 million times, that is 1 million loading cycles, in this test. Throughout the test, the maximum stress was around 140 N/mm^2, the maximum deflection was around 3 mm, the maximum gap at the connection was no greater than 0.01 mm and no damage was observed at all. Satisfactory results have been obtained from every viewpoint. Thus it has been verified that the cast iron bridge deck is qualified for highway bridges. (Fig. 3)

Fig. 1 Trial product of spheroidal graphite cast iron bridge

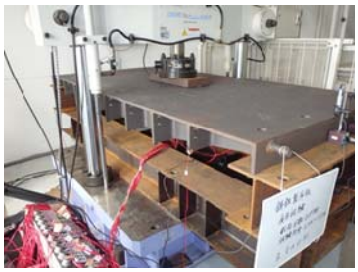

Fig. 2 Fatigue test with the non-moving loading

Fig. 3 Fatigue test with the wheel moving load

4. Papers for Presentation

1) **E. Yamaguchi**, H. Tobinaga, M. Murayama, T. Umetani: Development of Cast Iron Deck Slab, Bridge and Foundation Engineering, Vol.51, No.8, pp.38-41, 2017.8

2) H. Tobinaga, M. Murayama, E. Saeki, T. Tamakoshi, **E. Yamaguchi**, C. Miki: Fundamental Study of Application of Spheroidal Graphite Cast Iron to Deck Slab for Highway Bridge, Steel Construction Engineering, Vol.24, No.95, pp.13-24, 2017.9

3) H. Tobinaga, **E. Yamaguchi**, M. Murayama: Consideration of Plastic Deformation Capacity of Spheroidal Graphite Cast Iron Deck Slab for Highway Bridge, Journal of Structural Engineering, Vol.64A, pp.109-119, 2018.3

4) H. Tobinaga, **E. Yamaguchi**, M. Murayama: Study of Fatigue Properties of Cast Iron Deck Slab, Annual Meeting of West Branch of Japan Society of Civil Engineers, pp.59-60, 2018.3

5) **E. Yamaguchi**, H. Tobinaga, M. Murayama: Development of Durable Bridge Deck for Highway Bridge: Application of Spheroidal Graphite Cast Iron, 2nd International Conference on Engineering Innovation (ICEI 2018), Keynote Lecture, 2018.7

6) H. Tobinaga, **E. Yamaguchi**, M. Murayama: Mechanical Properties of Spheroidal Graphite Cast Iron Deck Slab, Annual Meeting of Japan Society of Civil Engineers, 2018.8 (to appear)

7) H. Tobinaga, **E. Yamaguchi**, M. Murayama: Development of Ductile Cast-Iron Deck for Highway Bridges, 12th Japanese German Bridge Symposium, Keynote Lecture, 2018.9 (to appear)

8) **E. Yamaguchi**, H. Tobinaga, M. Murayama: Ductile Cast-Iron Deck for Bridge, International Conference on Structural and Civil Engineering Research 2018, Keynote Lecture, 2018.10 (to appear)

9) **E. Yamaguchi**, H. Tobinaga, M. Murayama: Cast Iron Deck Slab for Highway Bridge, Ninth International Conference on Advances in Steel Structures (ICASS2018), Keynote Lecture, 2018.12 (to appear)

5. Study Development and Future Issues

・Application of a cast iron bridge deck to the highway bridge project of the replacement of a bridge deck and/or new bridge construction.
・Implementation of the research outcome in the mass production technology and the quality control.
・Further application of cast iron to other civil infrastructures to take advantage of its features.

6. Contribution to Road Policy Quality Improvement

Various tests and analyses have been conducted for the development of high performance cast iron bridge deck in this research. It has been confirmed that the cast iron bridge deck made of spheroidal graphite cast iron is advantageous in fatigue resistance, weight and construction speed. Moreover, it may as well be emphasized that the cast iron bridge deck can be replaced partially as it consists of panels. Hence, it is believed that the cast iron bridge deck can make a substantial contribution to the project for the replacement of bridge deck.

7. References, Websites, etc.

None.