THE CLASSIFICATION CODE SYSTEM FOR ARCH BRIDGE IDENTIFICATION

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SUMMARY

There are too many different kinds of arch bridges, because the adequate type and shape of arch bridges depends on its length, size, location, and conditions of construction. The type and shape of arch bridges also depend on other conditions such as material, bridge shape, support conditions, deck location, rib number, hanger arrangement, and also have special shapes. In this paper, systematic classification code was proposed to distinguish the diverse arch bridges, so that the arch bridges can be managed more efficiently. It will also be helpful for analysing the detailed components of arch bridges and for developing the technologies of arch bridges. The arch bridge code has three code in its shape and four code in its size, and four more in other properties.

Keywords: *Arch bridge, classification code, bridge type, bridge length, support condition, deck location, hanger arrangement.*

1. INTRODUCTION

Arch bridges have been constructed and beloved for a long time, because of its authentic appearance. Arch bridges are also very structurally efficient system which can carry high loads. There are 8,997 arch bridges in US, 2,536 arch bridges in Japan, and only 136 arch bridges in Korea. However, if it comes to Europe and China, the number of arch bridges are so many, and the statistics are clearly established.

Old arch bridges were mainly constructed with stone or wood. Before the introduction of steel and concrete, bridge structure should be designed to carry the load only in the compressive force. However, when steel and concrete have been introduced as new structural materials, they become the main material for the ribs of arch bridges. The two materials are not just used for the arch rib, which is the most difficult part of construction, but also for the other parts such as spandrel column, deck, cross beam, etc.

There are so many arch bridges were constructed, but the statistics of the arch is not clear. Most of the statistics distinguish the material and location of the deck, only. We can only recognize whether the bridge is made of steel or concrete, and/or deck arch bridge or deck through arch bridge.

In order to find a more detailed information from the statistics about the arch bridges, a classifying method of arch bridge and a coding system have to be developed. The proposed coding system could give us a more detailed information of the arch bridges and the information might help for the engineers to design the better arch bridges systematically. Still the remaining difficulty is whether the variable height girder bridge could be classified as arch bridge or not.

2. COMPONENTS OF ARCH BRIDGE

Main components of deck arch bridge are shown in Fig. 1. Truck load is supported by deck and transferred to arch rib through spandrel column. The length and the height of arch bridge is different from those of arch rib. And the rise ratio is defined as the arch rise divided by the arch length.

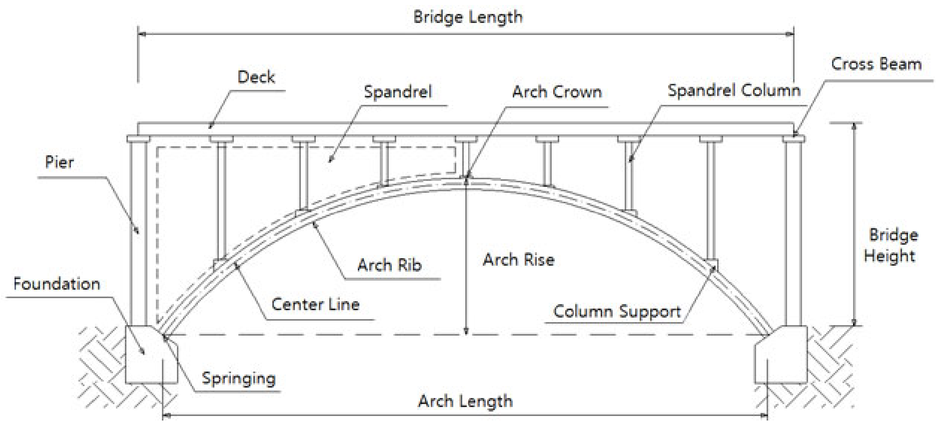
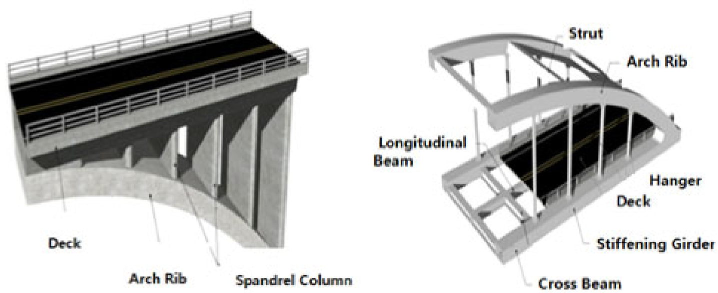


Fig. 1. *Outline of Arch Bridge.*

Through deck arch bridge is compared to the deck arch bridge in Fig. 2. Strut connects the arch ribs and hanger is similar to the spandrel column. But the stiffening girder is different and it ties the both ends of the rib and transfer the load to the arch rib through hanger. The stiffening girders are connected with cross beam which support the deck.



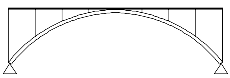
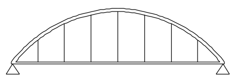
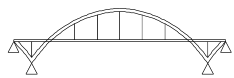
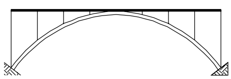
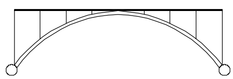
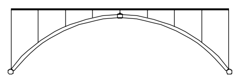
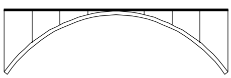
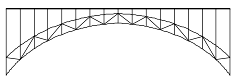
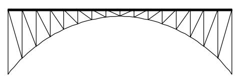
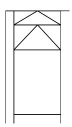
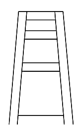
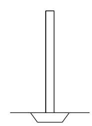
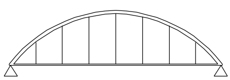
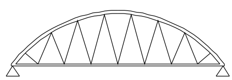
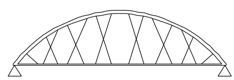
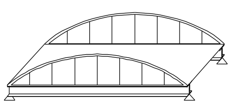
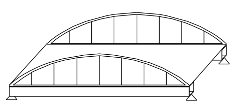
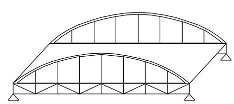
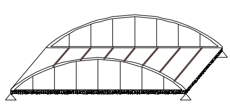
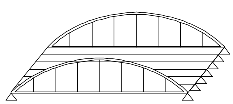
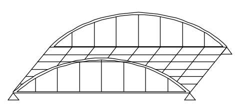
a) Deck Bridge *b) Through Deck Bridge*

Fig. 2. *Deck Arch Bridge and Through Deck Bridge.*

3. CLASSIFICATION OF ARCH BRIDGE

Arch bridges are classified by eight conditions, including the road position, support condition, rib shape, rib alignment, hanger shape, stiffening girder type, stiffening girder section, and deck structure. The classification of the arch bridge is shown in Table 1.

Table 1. *Classification of Arch Bridge.*

Sort	Classification		
Deck Location	 Deck Arch	 Through Deck Arch	 Half-Through Arch
Support Condition	 Fixed arch(H0)	 2 Hinge arch(H2)	 3 Hinge arch(H3)
Rib Shape	 Solid rib	 Braced rib	 Braced Spandrel
Rib Design	 Parallel rib	 Inclined rib	 Single rib
Hanger Design	 Vertical	 Warren	 Double Warren
Girder Design	 I-section Girder	 Box Girder	 Truss Girder
Slab Design	 Cross beam Slab	 Longertudinal Slab	 Grid type Slab

The most distinctive difference of the arch bridge is the location of deck. Deck through bridge and upper deck bridge, and the third type is half deck through bridge, which is the most efficient structure among the arch bridges. The arrangement hanger also shows a very distinctively different shape including vertical hanger, inclined hanger, and crossed hanger.

On the other hand, the support conditions of the arch rib and the presence of hinge at crown makes the arch rib structurally determinant and in determinant which depends on the number of fixed condition. The support conditions depends on the number of hinges at the support and crown. Nowadays, thanks to the development of structural analysis program, no hinge arch rib, a high degree indeterminate structure can be easily designed. However, during the construction, it is not easy to make the support condition as designed.

At the beginning of the iron arch bridge, three hinge arch bridge was the most popular, because of the limitations of the analysis technics.

The number of arch rib and the arrangement of arch rib can also be another criteria to classify the arch bridges. Single arch, double arch, and inclined arch, And also there are so many special type of arch bridges which are called Langer arch, Lohse arch, Nielsen arch, and etc. Most of them are a kind of tied arch bridges.

4. IDENTIFICATION CODE FOR ARCH BRIDGE

4.1. Proposed Identification Code System

Identification code defined in nine different conditions, including the material, number of span, road position, support condition, rib shape, rib alignment, hanger shape, stiffening girder type, stiffening girder section, deck structure, spandrel type and special arches. The identification code for the arch bridge is summarized in Table 2.

The first code for the arch bridge is material. Three codes, ‘C’ for concrete, ‘S’ for Steel and ‘O’ for composite material was assigned. And the number of span was indicated as ‘S_x’. For example ‘S_1’ is for single span arch bridge and ‘S*7*’ means 7 span multiple arch bridge.

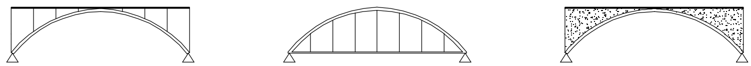
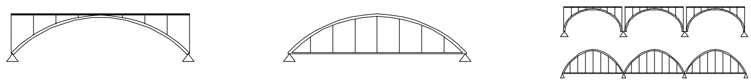
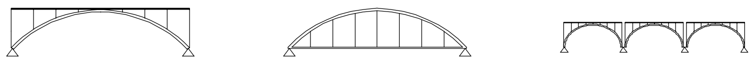
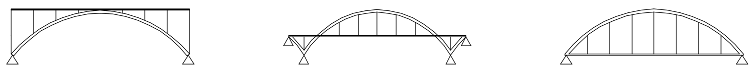
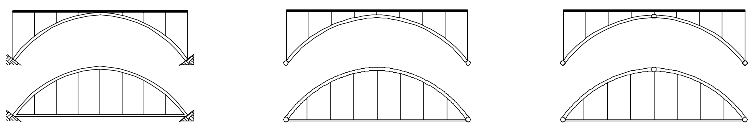
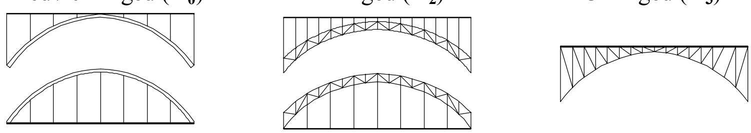
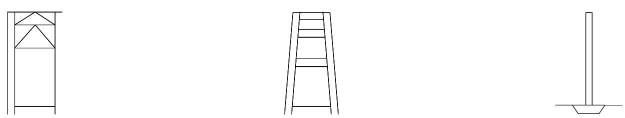
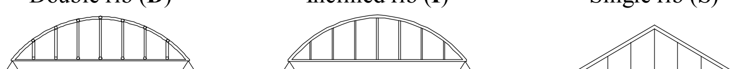
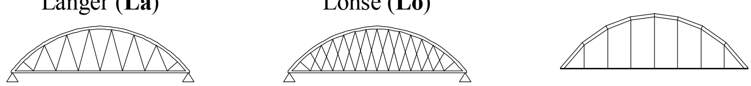
And the location of deck is indicated as ‘D’ for deck arch, ‘H’ for half deck arch, ‘T’ for through deck arch bridge. The support condition was indicated as ‘H_x’. For example ‘H_0’ is for fixed arch rib, ‘H_2’ for two hinge arch rib.

The type of rib can have three codes, ‘S’ means solid rib, ‘B_r’ and ‘B_s’ means braced rib and braced spandrel, respectively. However, solid rib has so many different cross section, such as rectangular, single box, multi box, slab, steel tube, CFT, combination of multiple tubes, and so on. Example of the cross section of the rib are shown in Fig. 3.

Closed spandrel arch bridge has a very long history. The closed spandrel is normally used for short span bridge or for heavy load carrying bridge such as soil covered animal passage. So, most of the arch bridges for traffic are open spandrel arch bridges. Sometimes, deck can be made continuous for structural advantage for deck arch bridge, so the simple bridge is designated as ‘S’ and the continuous girder as ‘C’. All through deck arch bridges are simple span, it cannot be made as continuous girder.

For the special type arch bridges, the first two characters can be used as the codes for them. ‘La’ is for Langer arch, ‘Lo’ is for Lohse, ‘Ni’ is for Nielsen, ‘Wa’ is for Warren. ‘NF’ is used for Non Formal special arch bridge.

Table 2. Identification Code for the Type of Arch Bridge.

Sort	Classification		
Material	Concrete (C)	Steel (S)	Composite (O)
Spandrel			
	Open Spandrel (**O**)		Closed Spandrel (**C**)
Span			
	Single Span ($\mathbf{S_1}$)		Multi Span ($\mathbf{S_3}$)
Bridge Type			
	Simple Girder (**S**)		Continuous Girder(**C**)
Deck position			
	Deck Arch(**D**) (Upper route bridge)	Half-through Arch(**H**) (Middle route bridge)	Through deck Arch(**T**) (Lower route bridge)
Support			
	Fixed / 0-hinged ($\mathbf{H_0}$)	2-hinged ($\mathbf{H_2}$)	3-hinged ($\mathbf{H_3}$)
Rib type			
	Solid Rib arch (**Sr**)	Braced-rib arch (**Br**)	Braced Spendrel arch (**Bs**)
Arch Member Position			
	Double rib (**D**)	Inclined rib (**I**)	Single rib (**S**)
Arch type			
	Langer (**La**)	Lohse (**Lo**)	
			
	Nielsen (**Ni**)	Warren (**Wa**)	Non Formal (**NF**)

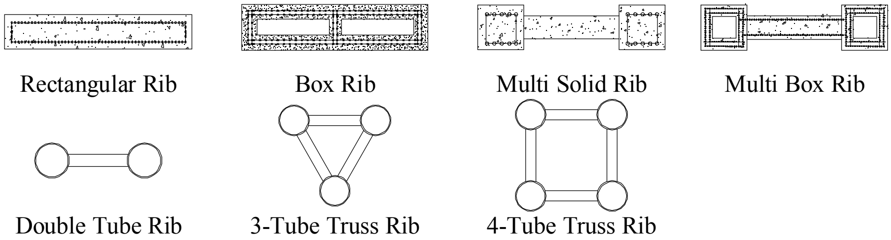


Fig. 3. *Cross section of arch rib.*

4.2. Application of Code System

Example of code system are shown below.

Fig. 4 shows the code for the "Harbour bridge" in Australia is "S-O-S-S-H-H2-Br-D". The 1st 'S' means it's material is Steel, 2nd 'O' means Open spandrel, and the subsequent codes indicate Single span, Simple Girder, Half through deck, 2hinge arch, Braced rib, and Double rib Arch bridge.

Fig. 4. *Code for Harbour Bridge in Australia, " S-O-S-S-H-H2-Br-D".*

Fig. 5 shows the code for the "Wanxian bridge" in China is "C-O-S-S-D-H_0-Sr-S". The 1^{st} 'C' means Concrete, 2^{nd} 'O' is for Open spandrel, and the subsequent codes indicate Single span, Simple Girder, Deck arch, Fixed support, Solid rib, and Single rib Arch bridge.

Fig. 6 shows the code for the "Gacheon bridge" in Korea is "C-O-S_2-S-D-H_0-Sr-D". The 1^{st} 'C' means Concrete, 2^{nd} 'O' is for Open spandrel, and the subsequent codes indicate Two span, Simple Girder, Deck arch, Fixed support, Solid rib, and Double rib Arch bridge.

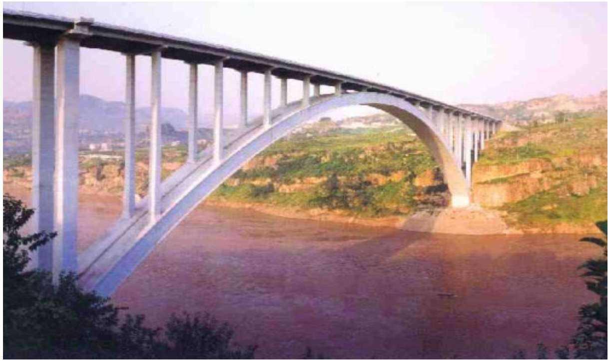


***Fig. 5**. Code for Wanxian Bridge in China, "C-O-S-S-D-H_0-Sr-S".*

***Fig. 6**. Code for Gacheon Bridge in Korea, "C-O-S_2-S-D-H_0-Sr-D".*

5. DISCUSSIONS

In this paper, classification code system for the arch bridge was proposed and some examples were provided. The code system might easy the complexity of the arch bridge. By systemize the classifying method of the arch bridge, the engineers can be easily understand the details of the ach bridges, just by looking at the code.

The code system should be modified and upgraded in the future, to make it simpler and easier and more representative code.

Identification code defined in nine different conditions, including the material, number of span, road position, support condition, rib shape, rib alignment, hanger shape, stiffening girder type, stiffening girder section, deck structure, spandrel type and special arches.

Arch bridges are classified by eight conditions, including the road position, support condition, rib shape, rib alignment, hanger shape, stiffening girder type, stiffening girder section, and deck structure.

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