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Emergency Deployable Bridge Development Process and Prospect

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Abstract: In the face of natural disasters or special circumstances, time is crucial. It is urgent to solve the problems of road damage and bridge collapse in the rescue process. Emergency deployable bridges can be quickly erected to restore road capacity, which can solve the above problems. This paper mainly summarizes the development process of emergency bridge, introduces the application of deployable structure, and summarizes the emergency deployable bridge.

1. Introduction

Natural disasters have never pity on human beings, hurricanes, floods, earthquakes and so on are likely to impact on human beings at any time. When disaster comes, innocent people are killed and a large number of people are displaced. At this time, the most needed rescue is speed. According to Bischmann's study, 80 per cent of the world's barriers to ditches, valleys and ravines require bridges to cross[1] . As the connection channel of various regions, road and bridge, once damaged or damaged to varying degrees, will lead to disaster relief operations become difficult and delayed. The existing road and bridge repair methods often take a long time, so the rapid erection of emergency bridges with strong carrying capacity is the key to rescue.

Paper made of cannabis and a small amount of ramie fiber appeared as early as the Western Han Dynasty, while the art of paper folding originated in China in the 1st or 2nd century A. D., and then spread the art of paper folding to Japan and flourished in Japan by Gaogouli Monks ' Tan Zheng[2]. Nowadays, folding paper technology has not only made achievements in art, but also has gradually been widely used in engineering, medicine, aviation, biology and many other fields. The deployable structure derived from folding paper technology has attracted the attention and research of many researchers and industries. The deployable structure, also known as foldable structure, has the function of contraction folding and extension expansion. When contraction folding, the volume and occupied area of the structure are small and easy to transport. When extension expansion, the structure is fast and extensible.

The application of the concept of deployable structure to the structural design of emergency bridges is a hot topic in the current research of bridges. This paper will review the development process of emergency bridges, focus on the deployable structure and the progress of the technology of emergency deployable bridges, and finally discuss the conclusions and prospects of emergency deployable bridges.

2. Research Status of Emergency Bridges at Home and Abroad

2.1 Domestic Emergency Bridge Research

The research of bridge in China started relatively late, and the research of national defense traffic emergency engineering structure began in the 1950s. After decades of development, some achievements have been made. At that time, the commonly used emergency bridges were mainly fixed bridges, highway composite suspension bridges, highway suspension bridges, and floating bridges. The development of floating technology was relatively mature, such as the developed railway floating bridges and highway floating bridges for military and civil use [3]. In 1990, the multi-purpose floating box developed by Chen Dinghua Engineer was marked with a main dimension of 5 ×2.5 ×1.5m [4]. It can not only meet the requirements of highway ordinary vehicle transportation, but also combine multi-purpose floating box with railway equipment (such as 64 -type military beam) to form railway floating bridge.

Although some achievements have been made after decades of development, there is still a big gap in the research of frontier technology compared with foreign countries. At present, China' s emergency bridges are divided into prefabricated highway steel bridges and mechanized bridges[5]. Emergency fabricated steel bridge, also known as Bailey steel bridge, is a semi-permanent bridge with strong bearing capacity and convenient splicing based on Bailey steel truss bridge made in the UK and combined with domestic technical and practical application requirements. China's existing prefabricated highway steel bridges are mainly divided into '321' type and HD200 type, which play an important role in military transportation, civil bridges, emergency and disaster relief [6]. Mechanized bridge has the advantages of fast erection and disassembly, which is mainly used for temporary emergency operations. At present, the mechanized bridges developed in China are divided into three series: light, heavy and special bridges, which can meet the requirements of different situations.

With the development of the times, modern bridge design needs to consider convenience and applicability. As shown in Fig. 1, engineers such as Leng Jianxing designed a folding assembled vehicle-mounted bridge. The bridge was divided into the first bridge body and the second bridge body for splicing, which can greatly reduce the transportation requirements and accelerate the erection speed [7].

2.2 Foreign Emergency Bridge Research

The design and production of emergency bridges appeared earlier in the 1940s. The most representative is the Bailey Bridge composed of modular panels designed by British engineer Donald Sie Bailey. Its military tactical status and performance are particularly important, and it is still used in many parts of the world [8]. As shown in Fig. 2, Bailey Bridge can carry about 45 tons of weight, with a length of 3.05 m and a width of 1.52 m. It is composed of prefabricated high-strength steel bridge base, bridge deck, beam, longitudinal beam and connecting member [9]. Then the Bailey suspension bridge was derived and designed. Although the construction time and difficulty of the suspension bridge were larger than those of the general bridge, it was the best choice at that time when the army needed to cross the barriers such as the canyon and mountain mouth. After the optimization design of Bailey Bridge for a generation, the Bailey System was further improved by the patents developed by Forsyth et al. In 2003, and the modular system for site construction was proposed, which can meet the requirements of larger panel width and strength, and reduce the packaging size and cost of transportation [10]. In 2004, Dimarco designed a dry support bridge, as shown in figure 1-3, using a vehicle launcher system that would allow only eight soldiers to complete the 40m-span erection in a short time[11]. After World War II, initially dedicated to military bridges, such as impact bridges, floating bridges, Bailey Bridge, with the development of the times, gradually used in civil life, disaster relief and rescue.

In 2010, Rhode-Barbarigos et al. designed the tensegrity module of the pedestrian overpass. The overpass is composed of four identical tensegrity modules. The internal space is 2.5 m high and the width is 1.3 m wide. The planned sidewalk can cross a river of 20 m[12]. By applying the load, the author compares the deflection, self-weight and internal space of the three forms of quadrilateral, pentagon and hexagon, and finally obtains that the pentagon has the highest efficiency. In 2017, Yuki Chikahiro et al. designed a new type of foldable deployable bridge based on shear mechanism. The maximum span of the bridge was 17.3 m, the width was 3 m, the height was 5 m, and the deployment time was about 5 to 10 min [13]. The author carried out finite element analysis and model experiment on the bridge to verify the safety and practicability of the bridge.

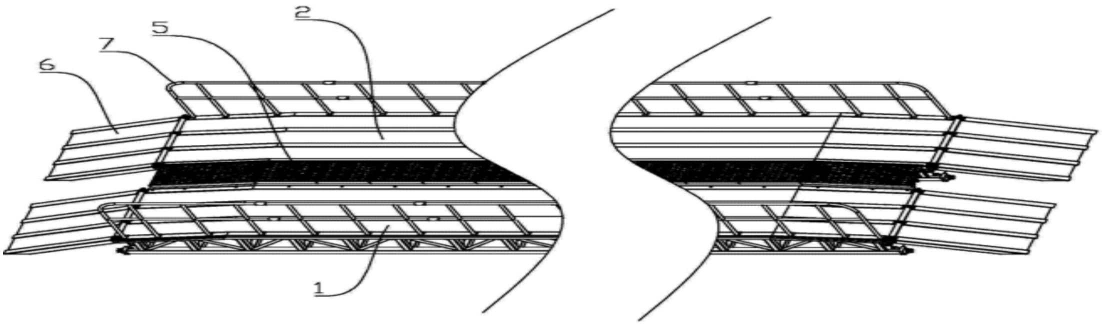

Figure 1: Folding assembled vehicle-mounted bridge

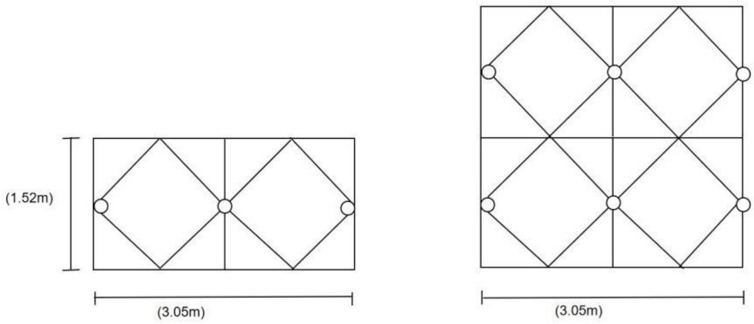

Figure 2: 1945 Bailey Bridge

Figure 3: Dry Support Bridge (DSB)

3. Application of Deployable Structure

The deployable structure can be converted from a folded, compact or contracted form to a set expansion or expansion structure, and the expanded structure is stable and can withstand loads[14]. In the transportation process, the structure is folded, small size and convenient transportation, and the operation is simple. At present, deployable structures have been widely used in aerospace engineering, civil construction, biotechnology, medical equipment, military equipment and other fields [14–16]. In the field of aerospace, rocket space is limited, the structure that can shrink and expand occupies less space and is widely used, such as the receiver of electromagnetic radiation transmitter, antenna, solar collector and so on. In the field of biotechnology, deployable structures can be used in bio bionics, studying the eclosion process of winged organisms can explore new spatial deployable structures and deployable membrane structures. In the field of military equipment, it is used for emergency bridges, parachutes, emergency shelters, convenient communication equipment, etc.

4. Development of Extensible Bridges

The following will focus on the application of deployable structures in the field of civil engineering - deployable bridges. The emergency deployable bridge was initially applied to the military. In 1992, the foldable three-dimensional triangular truss mountain footbridge developed by Guangzhou Military Region Engineering Research and Design Institute is shown in Fig. 4, which is composed of triangular truss, beam, suspender, anchorage, steel cable and bridge plate, and can ensure the passing of the command vehicle of 2000 Kg at most[17]. In 2007, engineer Li Zhenzhong designed a self-propelled deformable multi-purpose emergency bridge, belonging to the vehicle-borne bridge type[18].The bridge consists of a driving control room, a sealing chamber, a hydraulic telescopic bridge column, a rotating rod, a crossbeam, and a leading bridge. Compared with the previous general emergency bridge, the bridge is special because its driving control room has the sealing waterproof function and can be erected in harsh geographical environment. If the two sides of the disaster relief channel are submerged, the ordinary emergency bridge needs to be erected on the flat land on the shore, but the bridge can be directly launched in the water smoothly and quickly.

In 2012, Guan et al. designed a light deployable military bridge as shown in Fig. 5. The whole bridge was made of aluminum alloy with a total length of 16m [16]. The bridge side adopts shear hinge, the lower chord adopts chain rod, and the bridge deck is connected with sleeve. The finite element software ANSYS and self-compiled program were used to analyze and simulate the bridge, and the scaled model was made for experiments. Finally, the correctness of bridge design and the scalability of deployable structure were verified. With the development of the times, the deployable bridge not only needs to withstand large loads, but also needs its light weight, easy to carry.

In 2014, Teixeira et al. designed a deployable GFRP truss beam as shown in Fig. 6. The bridge span was 13 m, which was composed of prestressed tubular GFRP truss and heavy-duty steel joint installation [19]. Because the FRB composite material used has the advantages of high strength, low specific gravity and corrosion resistance, the bridge made of it also has the advantages of large bearing capacity and light weight. In 2017, Professor Li Runcheng designed a new type of tripod emergency bridge (as shown in Fig. 7) according to the scissors and winding structure, and conducted a full-scale model experiment. The application of external load verified that the bearing capacity of the bridge met the requirements [20]. The total span of the bridge is 10.47 m, which is mainly hinged by the shear fork structure and pin shaft. The material used in the structure is light aluminum alloy, which can not only reduce the overall weight of the bridge and facilitate transportation, but also withstand 10 KN vehicle load.

In 2019, Chanthamanivong et al. designed the deployable pedestrian overpass and proposed a new ecological construction method as shown in Figure 4-8[21]. The overpass has little impact on the surrounding natural environment and can better protect the environment. It is believed that it can be widely used in scenic spots in the future. In 2020, Yan et al. designed and optimized the scissors deployable bridge as shown in Fig. 9[22], which consists of five main parts: deck, pin shaft, cross shaft and deck shaft. The author uses stress analysis and thermal analysis to analyze and optimize the bridge. The bridge deck with open grid greatly reduces the overall weight and is easy to transport.

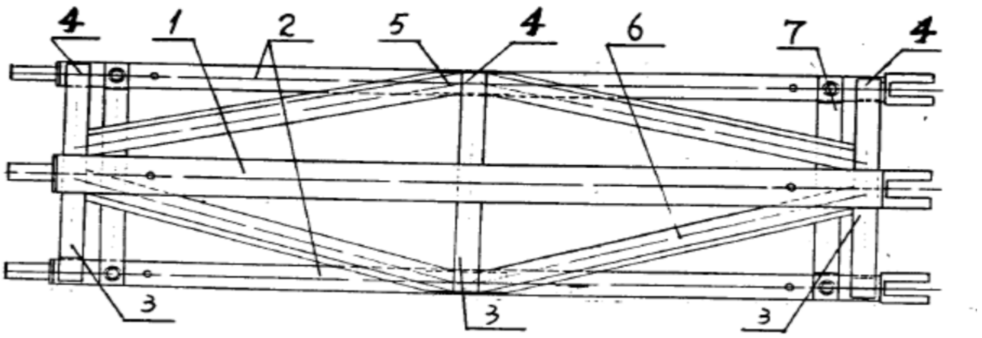

Figure 4: Foldable footbridge

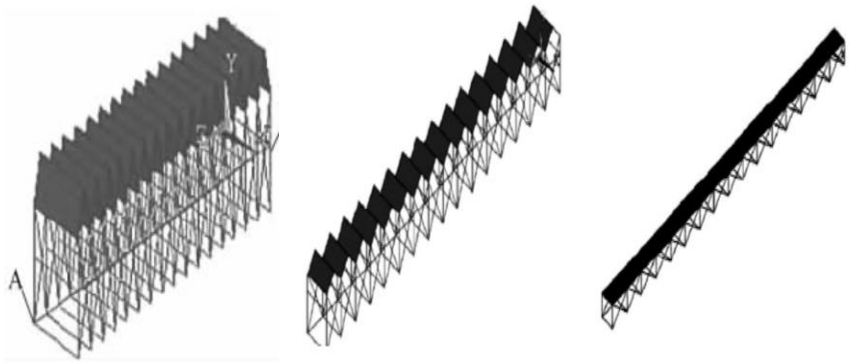

Figure 5: Light deployable military bridge

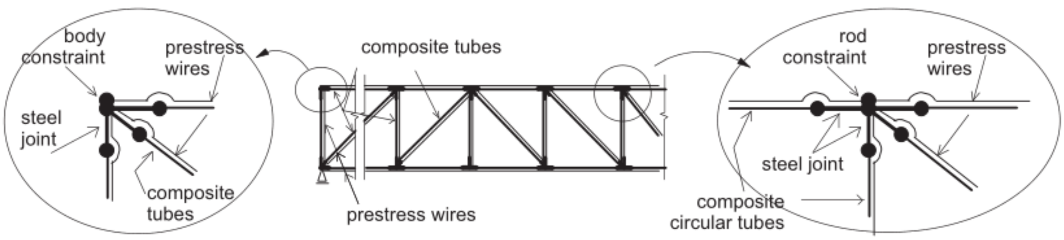

Figure 6: Numerical model of truss beam

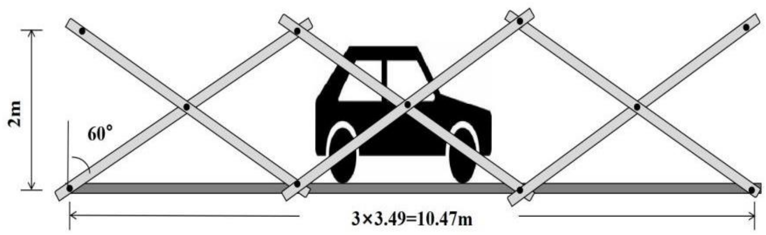

Figure 7: Three - shear bridge schematic

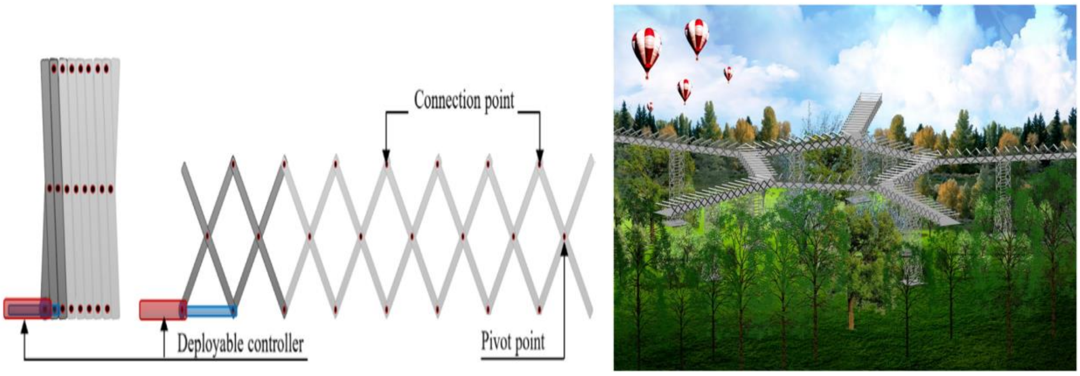

Figure 8: Extensible overpass

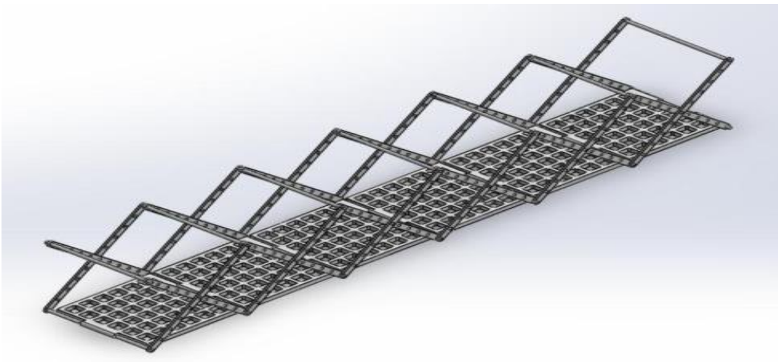

Figure 9: Emergency bridge with open grid deck model

5. Conclusions

In view of the research and development of emergency deployable bridges in China, the following suggestions are put forward:

(1) Attention should be paid to the weight of deployable bridges. In the case of ensuring the strength of the bridge, the weight is reduced as much as possible to facilitate the transportation and erection.

(2) Actively develop new materials and apply them to the structural design of bridges. Such as fiber reinforced polymer (FRP), the material has high specific strength, can reduce the weight of the structure, corrosion resistance, fatigue resistance, can be used in special environment for a long time.

(3) Research and formulate the standards of deployable bridge erection technology to ensure the smooth development and recycling of the structure.

(4) Actively developing the structure of new deployable bridges. At present, many deployable bridges are mainly designed based on scissors structure, and later research can break through to connecting rod structure and suspension cable.

(5) Exploring the application of prestress in deployable structures. Prestressed composite structure spanable bridge can better maintain stability and increase overall strength when it expands or bears load.

This paper not only introduces the technical development of emergency bridges and the application of deployable structures, but also focuses on the research of deployable bridges, aiming to provide reference for the research and application of this new bridge structure.

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