RESEARCH AND PROPOSE A MODULARIZED PRE-FABRICATED BRIDGE DECK FOR FAST DEPLOYMENT IN RESCUE WORKS

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Abstract

In this study, the authors investigate and study the mechanical and physical properties of lightweight materials, propose and apply it to produce a fast deployed bridge deck that suitable with Vietnamese conditions, ensuring vehicles to overpass through landslides and separated locations (with a span of about 30÷35 m) on traffic routes caused by the influence of rainstorms, keeping the clearance of the route, allowing vehicles up to 5 tons weight (light trucks) can travel and approach isolated areas for deployment of rescue works. To determine the scope of application of the bridge plan for each specific case, the authors used the finite element method to build a computational model and perform a numerical survey with variable parameters, such as: span layout, span length, load over bridge,…

Keywords: *Landslide; temporary bridge; lightweight materials; aluminium alloy; quick assembly; rescue.*

1. Introduction

Every year, in our country, floods and storms cause landslides, particularly on traffic routes. Landslides on roadways cause division and isolation between communities and roads. Rescue and recovery will be extremely difficult, especially in villages and locations which are remote from the center. Access to timely information, as well as relief of commodities and necessities meets numerous challenges and takes a long time, causing regrettable incidents resulting in the loss of life and property.

Figure 1. Rain and flooding caused a landslide on the road.

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Several types of assembled steel bridges are currently being built in countries around the world, including the Bailey bridge (designed by the British between 1940 and 1941), the Taypan bridge (designed by Russia), and others. Temporary bridges are often used for military vehicles and other vehicles. However, due to the large loads for vehicles crossing the bridge, the components built into the bridge have large sizes and weights to assure the bridge's safety. This results in a lengthy installation time as well as a lengthy disassembly time [1, 2]. Furthermore, the deployment and installation of steel bridges will be problematic in bad weather and terrain conditions.

Table 1 shows the parameters of the pre-fabricated bridge type, which is now used in several countries throughout the world.

Table 1. The pre-fabricated bridge type

#	Country	Authors	Bridge name	Length, m	Load over bridge, T	Time to finish the bridge assembly
1	Russia	D.V. Poroshenko, R.A. Sarsov, and D.N. Pakhomov	Taipan	3÷60	80	(10÷12) h
2	Russia	-	TMM	10.5	60	
3	Canada	-	LVTB	24		90 mins
4	US military	-	M60 AVLB	18	70	10 h
5	US military	-	JAB M1074	11	60	3 mins

The Light Vehicle Tactical Bridge (LVTB) [4], popularly known as the "Bridge in a Box," was designed by MAADI Group (Canada) and is primarily built of aluminum profiles 6005A-T61 and 6061-T6 [5]. The bridge is meant to be easily erected on-site without the use of heavy machinery; to fully assemble the LVTB with a span length of 24 m, 6 soldiers are required, along with 28 bolts and basic tools and equipment. When ten soldiers were assembled, it took less than 90 minutes to complete.

All components of the LVTB bridge are fitted into a standard container (container - 20 ft, equivalent to 6 m). Containers can be transported by truck or train (intermodal) or even by helicopter (for fastest response). The bridge's self-weight is 4800 kg, when packed in its container with all attached equipment, the total weight is 9090 kg.

Figure 2. Container (20 ft) for LVTB-241 bridge.

Table 2. Specifications for LVTB-2418 bridge

Specifications	**LVTB-2418**	
Span length	4.02 m (1 panel) 8.04 m (2 panel) 12.06 m (3 panel)	16.08 m (4 panel) 20.10 m (5 panel) 24.12 m (6 panel)
Width	2.13 m - 7’-0”	
Self-weight of the bridge	4503 kg - 9927 lb	
Vehicle load over the bridge	2268 kg - 5000 lb	
Human load	3.5 kPa	
Container	Container 6 m (20 ft)	
Combination	- 24.12 m (6 assembled panels); - Assembly is less than 90 minutes (with 10 soldiers); - Requires a minimum of 6 soldiers to deploy and install the bridge.	

Figure 3. Equipment and assembly process of LVTB-2418 bridge.

In Vietnam, Bailey bridges and assembled steel bridges have been utilized for a long time to act as temporary bridges to ensure the movement of military vehicles around barriers and to ensure traffic safety for vehicles during road construction. However, the installation and assembly also take a long time and require a lot of supporting means, as well as the construction of abutments and piers before the bridge can be assembled. During the construction process, if it encounters adverse weather conditions, it will cause a lot of difficulties, in many cases, it will be impossible to assemble the bridge.

Our army has also been equipped with a number of field bridges such as Bailey bridge, PMP pontoon bridge, TMM-3M... However, the quantity of bridge is small, the time of use is long, now these bridges are partially damaged. In special cases, the use of these types of bridges is difficult.

On the basis of the above urgent problems, the requirement is to have a specific solution to quickly assemble steel bridges without having to build abutments and piers. The above bridges serve to connect traffic between areas and participating in rescue and rescue is necessary.

In this study, the authors study the mechanical properties of a lightweight material for the bridge. At the same time, it is proposed and applied to a type of bridge diagram that can be assembled quickly in accordance with Vietnamese conditions, ensuring passing through roadway landslide, separation positions (with a span of 30 m), and allowing a load of 5 tons to flow through the bridge and access to isolated areas to do the rescue work.

2. The scientific basis is proposing bridge pre-fabricated for quick assembly

2.1. About the material making bridge

Steel is commonly utilized in the construction of bridges of all sizes, from the very large to the extremely little, all over the world. It is a versatile and effective substance that offers cost-effective and long-term solutions. Steel has long been recognized as the most cost-effective material for a variety of bridges. However, in order to reduce the weight of the bridge itself as well as transport and remove quickly, aluminum alloy materials are used for military bridges.

In recent times, in many countries around the world, aluminum alloy structures have been used for the main load-bearing structures of large-span buildings, roof trusses of sports buildings and bridges. Aluminum alloy offers numerous advantages, including high strength, light weight, and superior corrosion resistance than steel, minimal maintenance costs, and environmental friendliness. Currently, European countries, the United States, Canada, the Russian Federation, China... have many standards and research documents on aluminum alloy structures. The Eurocode standard was created by the European Community Commission's member countries, and Eurocode 9 is titled "*Calculation of Aluminum Structures*" [3].

Aluminum alloy materials have been developed and employed in Vietnam in recent years. However, there is no calculation standard, and there are just a few research articles on aluminum alloy structural calculation. Some basic mechanical and mechanical properties of aluminum alloy materials are presented in Table 3.

Table 3. Strength properties of wrought aluminum alloys

Alloy and Temper	Shape	Thickness (mm)		Minimum Limit (MPa)			
		min	max	Normal state		Welding position	
				F_u	F_y	F_{wu}	F_{wy}
5052-H32	Sheet	0.4	50	215	160	170	65
5086-H116	Sheet	1.6	50	275	195	240	95
6005A-T61	Extrusion	-	25	260	240	165	90
6063-T6	Extrusion	-	25	205	170	115	55
6061-T6, -T6510	Extrusion	All	-	260	240	165	80*/105**
6061-T6	Sheet	0.15	6.3	290	240	165	105
6061-T651	Sheet	6.3	100	290	240	165	80*/105**
6082-T6, -T6511	Extrusion	5	150	310	240	190	110

From the table above, it can be seen that the yield strength F_y and strength F_u, of aluminum alloys are lower than those of steel. However, the density of aluminum alloy (ρ is 2700 kg/m^3) is approximately 1/3 of the density of steel. The strength of aluminum alloys is significantly reduced locally due to the conventional welding process (arc welding). This is a difference to note between aluminum and steel, which must be taken into account in the design. The impact of this loss of strength can be reduced by reducing transverse welds and using longitudinal welds. Friction stir welding (FSW), a new welding method, was introduced in 1991. It is an olid method that generates high-quality welds with little energy input, and it is been created to make welds with extremely high strength.

The elastic modulus of aluminum alloy under normal conditions is E is 70000 MPa, at a temperature of 100^{o}C - E_{100} is 67000 MPa, at a temperature of 200^{o}C - E_{200} is 59000 MPa. Aluminum has a coefficient of thermal expansion, α is 24.10^{-6}/^{o}C, approximately twice that of concrete or steel.

The mechanical and physical properties of the bridge materials utilized, aluminum alloys 6005A-T61 and 6061-T6, are provided in Table 4.

Table 4. Mechanical and physical parameters of aluminum alloy 6005A-T61

Specifications		**Aluminum alloy**
Parameters		6005A-T61
Specific weight	ρ (kG/m^3)	2700
Modulus	E (MPa)	70 000
Coefficient of thermal expansion	α (/^{o}C)	$24 \cdot 10^{-6}$
Yield strength of aluminum alloy	F_y (MPa)	240
Value of ultimate tensile strength	F_u (MPa)	260

2.2. About the structure bridge

The authors propose a bridge diagram to conduct the survey based on the light vehicle tactical bridge (LVTB). The bridge is made up of modules with a length of 4.0 m, a height of 1.2 m, and a width of the bridge of 3.4 m (Figure 4). Table 5 shows the forms and sizes of the bars.

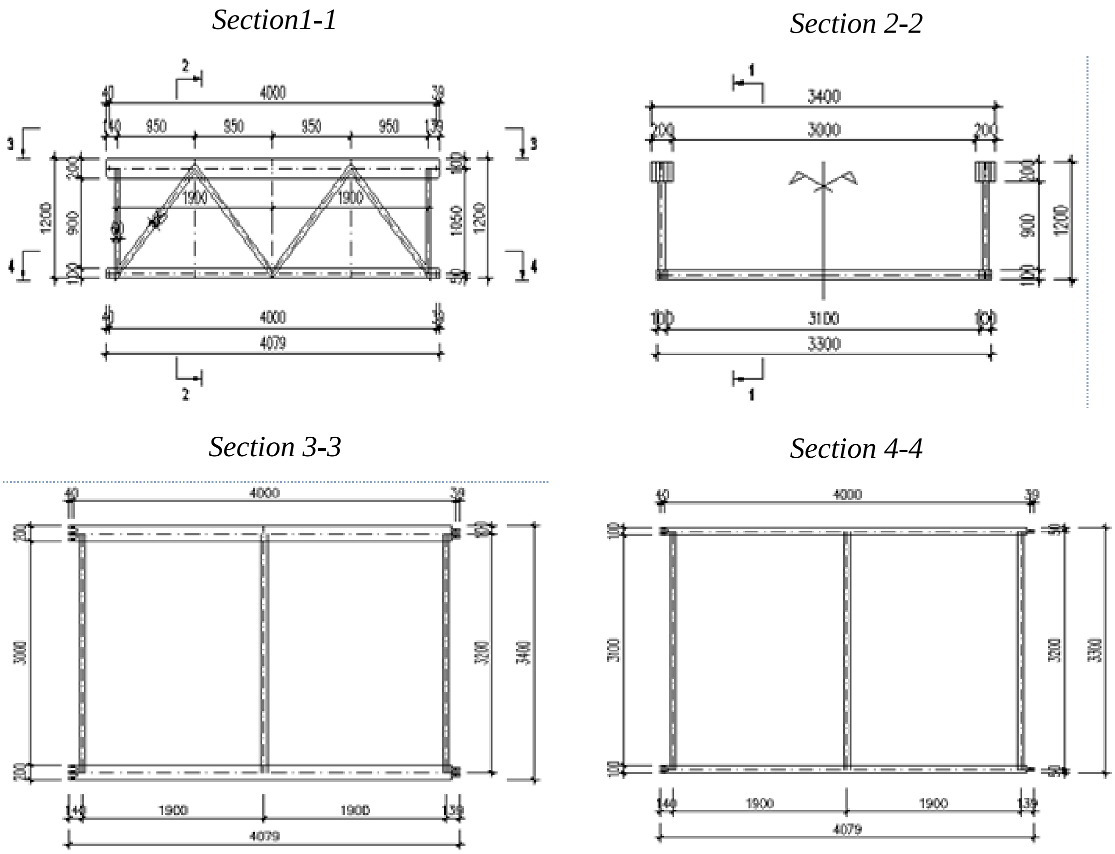

Figure 4. Proposed bridge module.

Table 5. Shape, size of truss rods

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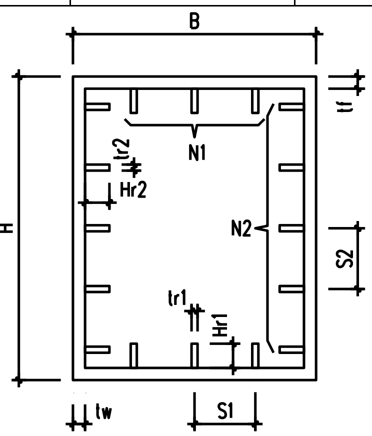
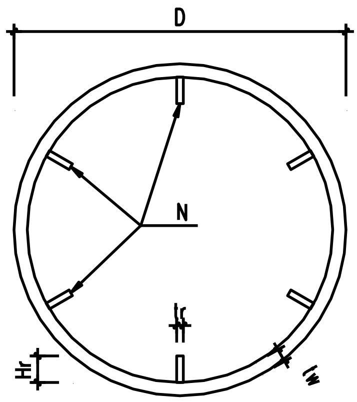
<tr><td>Upper border bar</td><td>Bottom border bar</td><td>Vertical bar</td><td>Oblique bar</td><td>Crossbar</td></tr>
<tr><td colspan="3">
</td><td colspan="2">
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3. Results and discussion

3.1. Model building and calculation results

Building a problem model in Midas Civil software [6] using the finite element approach to analyze the operation of parts in the bridge diagram, with changeable input parameters: bridge length (L is 8, 12, 16, 20, 24, 28 m); truss bar size; live load over the bridge (from 1.0 to 8.0 tons). Dimensions and loads over the bridge are illustrated in Figure 5.

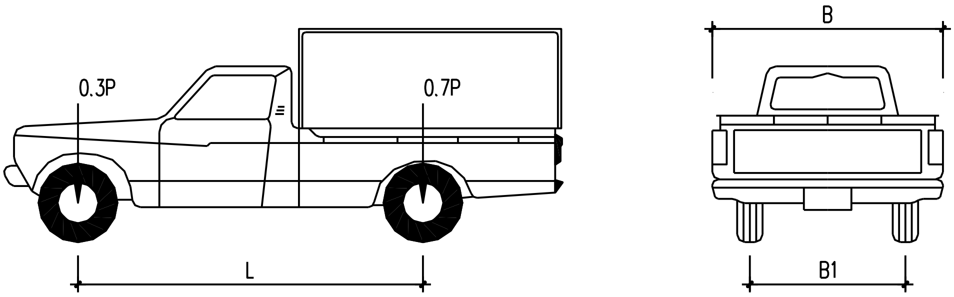

Figure 5. Shape, size of live load over bridge.

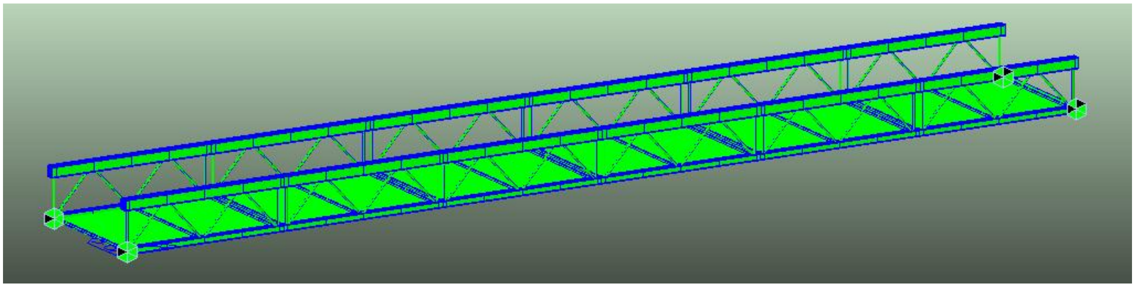

Figure 6. Computational model by Midas civil software.

Conduct a survey on a bridge model with a span length of L is 28 m and truss rods of various diameters and thicknesses. Determine internal force, truss bar stress, and perform an audit in accordance with Euro Code 9. With a vehicle weight of P is 2T, the vehicle loads across the bridge.

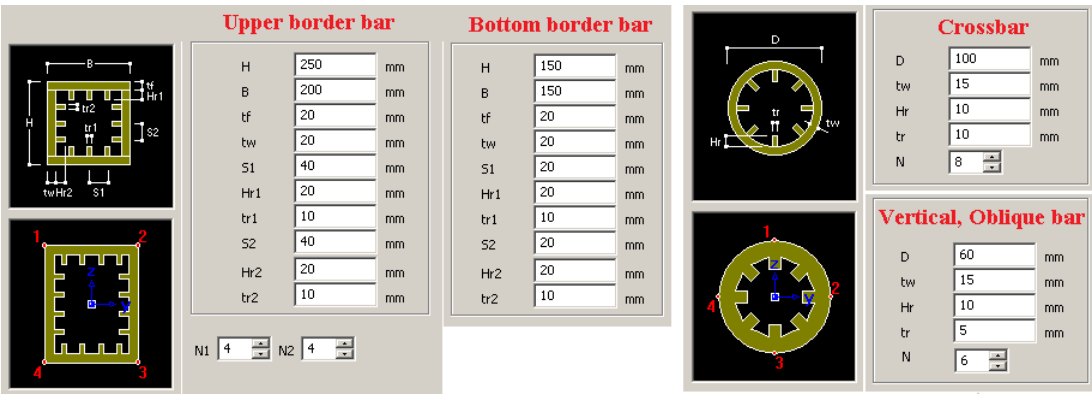

Figure 7. Shape, size of truss rods.

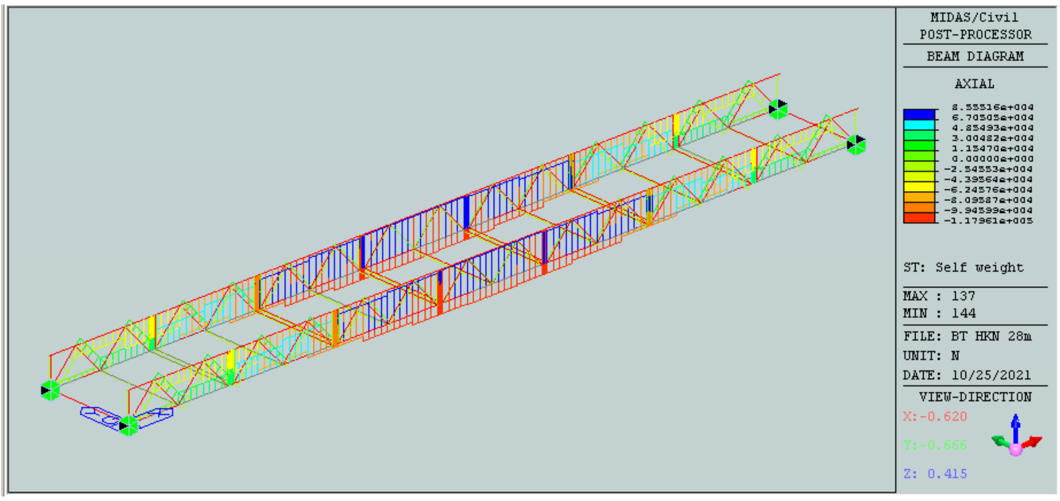

Figure 8. Results of stress values in truss bars.

With the size of truss rods found as above, continue to survey the problems with span length L is 8, 12, 16, 20, 24, 28, 32 m, respectively. The vehicle load over the bridge can be determined from 1.5T to 4.5T for each span structure length (Table 6).

Table 6. Allowable vehicle load over bridge corresponding to span structure length

Span length L (m)	8	12	16	20	24	28	32
Loads M (T)	4.5	3.5	3.25	3.0	2.75	2.0	1.5

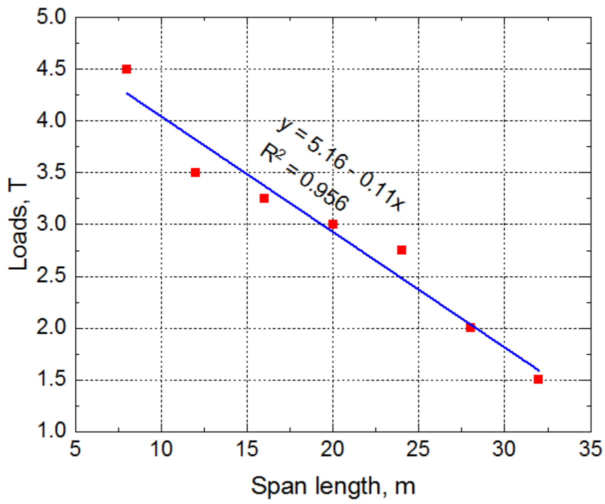

Figure 9. Relationship between load and span length.

From Figure 9 it can be seen that the relationship between the load over the bridge and the span length is linear. Using the linear programming method, we get the following regression equation: y = 5.16 – 0.11x with R^2 = 0.956 (where y is loads; x is span length).

3.2. Preliminary plan for bridge assembly

According to the dimensions of the truss rods determined above, the weight of one side of the truss panel is 4.0 m long and made of aluminum alloy weighing no more than 450 kg. This is convenient for the process of transporting, assembling, and dismantling the bridge. The preliminary proposal of the bridge assembly plan is as follows: The bridge is assembled on each side with a row of many panel frames linked together by dowels (or bolts) to form the main truss. Each module of the bridge consists of 2-panel frames, 3 cross beams, and 10 deck slabs [5, 6].

- *Step 1*: Install the bridge modules;

- *Step 2*: Place the balance rollers on the javelin;

- *Step 3*: Put the first bridge module on the balance rollers, connect the leading javelin to the first bridge module;

- *Step 4*: Use force to push the first bridge module forward, assemble, connect the second bridge module with the first bridge module by dowels (or bolts). Continue, use force to push the bridge modules forward and install the next modules;

- *Step 5*: When the bridge modules are assembled. When the bridge has overcome the obstacle, use two 5-ton jacks to jack the ball upwards, move the balance rollers, install the bridge bearings in place, lower the jacks, the span structure is placed on the bridge's bearings;

- *Step 6*: Complete the bridge work by installing the bridge deck panels.

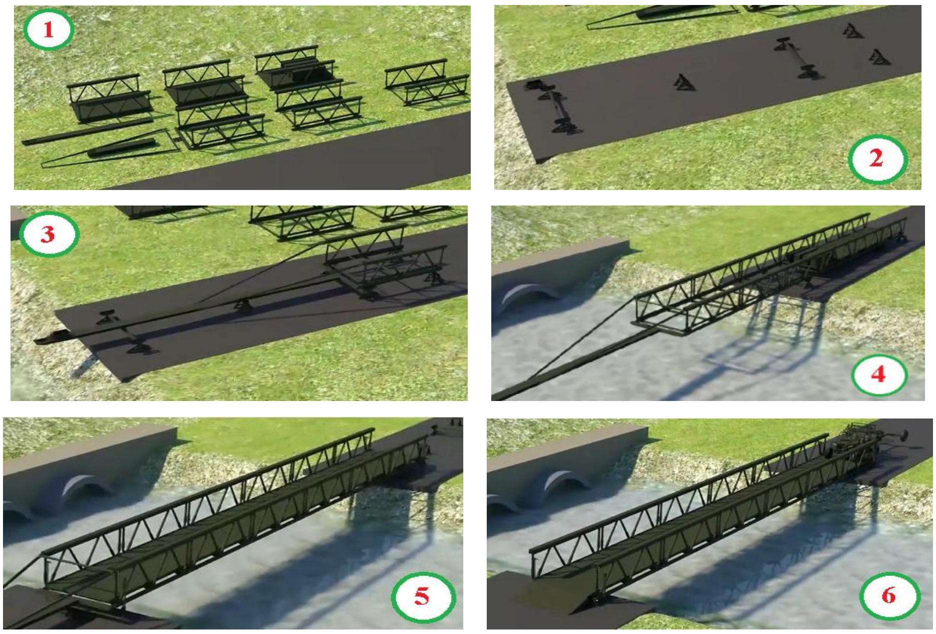

Figure 10. Bridge assembly steps [5].

4. Conclusions

Based on the research results, we draw the following conclusions:

- Proposed bridge construction materials and pre-fabricated bridge structure without abutments to overcome obstacles such as slots, trenches, and pits with a length of up to 32 m, a load of up to 4.5 tons across the bridge. Besides, the relationship between the load over the bridge and the span length in the form of a linear equation is as follows $y = 5.16 - 0.11x$ with $R^2 = 0.956$ (where y is loads; x is span length).

- The results of the study are used to develop a general approach for calculating, designing, and manufacturing quick-assembled rescue bridges.

- Directions for future research: Continue to optimize the detailed structure of the bridge's components and propose solutions for assembly and dismantling with different terrain conditions.

References

[1] Bailey bridge. Headquarters department of the army. Washington, 1986, 373 p.

[2] Бокарев С.А., Проценко Д.В., "Экспериментально-теоретические исследования пролетного строения сборно-разборного моста ТАЙПАН", Известия высших учебных заведений, *Строительство*, Выпуск №8, 2017, С. 28-33.

[3] The European Standard EN 1999-1-1:2007 has the status of a British Standard, Eurocode 9: Design of aluminium structures - Part 1-1: General structural rules.

[4] Design. Build. Aluminum. Aluminum Pedestrian Bridges and Structures, MAADI Group.

[5] Light Vehicle Tactical Bridges - LVTB-1811 and LVTB-2418, Make-A-Bridge - Modular Aluminum Pedestrian Bridge System, MAADI Group.

[6] MIDAS. Getting started American: MIDAS IT Co., Ltd., 2003, 237p.

NGHIÊN CỨU, ĐỀ XUẤT DẠNG CẦU LẮP GHÉP NHANH PHỤC VỤ CHO CÔNG TÁC CỨU HỘ, CỨU NẠN

Phạm Tuấn Thanh, Nguyễn Mạnh Hà, Nguyễn Trọng Chức

Tóm tắt: *Trong nghiên cứu này, nhóm tác giả tìm hiểu, nghiên cứu đặc tính cơ lý của một dạng vật liệu nhẹ, đề xuất, áp dụng cho một dạng sơ đồ cầu có thể lắp ghép nhanh phù hợp trong điều kiện Việt Nam, đảm bảo vượt qua các vị trí bị sạt lở, chia cắt (với bề rộng khoảng 30÷35 m) trên các tuyến đường giao thông do ảnh hưởng của mưa bão gây ra, đảm bảo thông suốt tuyến đường, cho phép các phương tiện có tải trọng khai thác đến 5 tấn (xe tải nhẹ) có thể lưu thông qua, tiếp cận kịp thời các vùng bị cô lập, thực hiện công tác cứu hộ, cứu nạn. Để xác định phạm vi áp dụng phương án cầu cho từng trường hợp cụ thể, các tác giả đã sử dụng phương pháp phần tử hữu hạn xây dựng mô hình tính toán và thực hiện khảo sát số với các tham số thay đổi, như: sơ đồ nhịp, chiều dài nhịp, tải trọng qua cầu,...*

Từ khóa: Sạt lở; cầu dã chiến; vật liệu nhẹ; hợp kim nhôm; lắp ghép nhanh; cứu hộ, cứu nạn.

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