

# RESEARCH ON THE APPLICATION OF GRATING PLATE AS BRIDGE DECK SLAB IN BAILEY QUICK ASSEMBLY BRIDGE

Manh Thuong Nguyen<sup>1,\*</sup>

<sup>1</sup>*Le Quy Don Technical University, Hanoi, Vietnam*

DOI: 10.56651/lqdtu.jst.v6.n01.673.sce

## Abstract

This article presents the calculation of the bearing capacity of the light-weight deck slab assembled from grating plates. The author uses the software SAP2000 on the basis of the finite element method to test the strength of this deck slab under the load of vehicles. From there, conclusions are drawn to build a scientific basis to determine the possibility of using grating plates as deck slabs for quick-assembled bridges serving security, defense, and rescue missions.

*Keywords:* Grating plate; deck slab; Bailey assembly bridge; load capacity; truck.

## 1. Introduction

In quick-assembled bridge structures such as Bailey bridge equipped, the deck slab is composed of steel longitudinal beams and wooden horizontal planks [1-3]. At present, with the development of science and technology, these deck slabs can be improved and replaced with lighter, pre-fabricated structures, and more convenient assembly, thereby improving the load capacity of the deck by reducing the static load [2, 4, 5]. Therefore, the use of deck slabs with light weight, made into assembled modules is urgent and it is necessary to study and propose an appropriate plan. Grating plate has many advantages to be able to replace this type of bridge deck. Grating panels have many advantages such as: light weight, made in sheets, just placed on the beam system, no need for longitudinal beams, very suitable for application in making deck slabs for assembled bridges as above [6]. In the framework of the article, the author presents the option of deck slab made from grating panels because this type of structure has many advantages suitable for assembling the bridge deck with light weight, quick construction for national security and rescue tasks.

## 2. Proposing the plan to use grating plate as the bridge deck

### 2.1. Overview of the grating plate

Product grating plate is made from steel (Figure 1). Grating panels are designed in a modular form, can be firmly connected together, so they have many advantages such as: easy to transport, easy to install, short installation time, low installation cost, light

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\* Email: [thuongnm@lqdtu.edu.vn](mailto:thuongnm@lqdtu.edu.vn)

weight, easy to change the shape of the structure at will, simple installation, high durability, safety... These grating panels can be made into a floor surface by joining these panels together (Figure 2). So it is possible to combine them to form a bridge deck.



Figure 1. Structure of grating plate.

Grating plate consists of bearing bars, usually made from steel, placed parallel to each other, to cross-link these main vertical bars together, cross bars are used, usually made from ribbed round steel.



Figure 2. Joining the grating panels into the floor.

## 2.2. The plan to install the grating plate into the deck slab

For Bailey bridge, the deck system consists of transverse beams, longitudinal beams and transverse planks. Instead of using longitudinal beams and deck slabs, grating sheets can be used directly on the horizontal beams, forming the deck slab. That is, the grating plate will replace the role of longitudinal beams and horizontal planks.

Using grating panels to replace longitudinal beams and horizontal paving slabs has the following advantages: the weight of grating panels per 1 m<sup>2</sup> of deck is lighter than the weight of longitudinal beams and transverse slabs over 1 m<sup>2</sup>. The grating plate has a fairly light weight of 1 plate. For example, a grating sheet with an area of 1 m<sup>2</sup> (1 m long, 1 m wide), composed of longitudinal bars with a cross section of 6 × 70 mm (*b* × *h*), spacing between bars 80 mm, horizontal bars from round steel d10 mm, the distance between the bars 150 mm has a weight of about 50 kg, easier to transport and install because if longitudinal beams and horizontal planks are used, the longitudinal beam alone has a weight of 115 kg, and in 1 m<sup>2</sup>, the deck slab has a weight is 90 kg/m<sup>2</sup> [2].

Table 1. Comparison of some parameters of two types of deck slabs

Name of quantity used to compare	Bridge deck from longitudinal beams and transverse planks of Bailey bridge	Bridge deck from grating
Self load/m <sup>2</sup> (kg)	90	50
Weight of 1 component (kg)	115	50

### 3. Surveying the bearing capacity of the bridge deck assembled from grating panels

#### 3.1. Building survey data

Conducting model selection for survey is the assembled Bailey bridge option with length  $L_{bri} = 15$  m, a cross section of 1/1, width  $B_{bri} = 4.0$  m, replacing conventional longitudinal beams and floorboards with grating panels with length  $L_{gp} = 1.5$  m, width  $B_{gp} = 0.4$  m. Select a grating plate with the dimensions of the bearing bars 1 with a rectangular cross-section of 6 × 70 mm, the distance between the bearing bars is 80 mm, the cross bar is from d10 mm round steel, the distance between the cross bars is 150 mm. Select a grating sheet of 0.4 × 1.5 m size. (0.4 m is considered as the width of contact area 1 wheel per module, length 1.5 m is the distance between transverse beams). The bearing bars ( $b \times h = 6 \times 70$  mm) are arranged longitudinally on the bridge, and the bearing bars and cross bars are welded together. The form of connection is the deck slab on the transverse beams beam linked by ledges.

Considering the vehicle load over the bridge is the Kraz 255B truck, with a load of  $P = 20$  tons (or 196.13 kN), in which the load on the wheel axles is  $P_1 = 5.49$  tons (or 53.84 kN),  $P_2 = 7.08$  tons (or 69.43 kN),  $P_3 = 7.23$  tons (or 70.90 kN) (Figure 3). This is a common type of truck equipped in our army today.

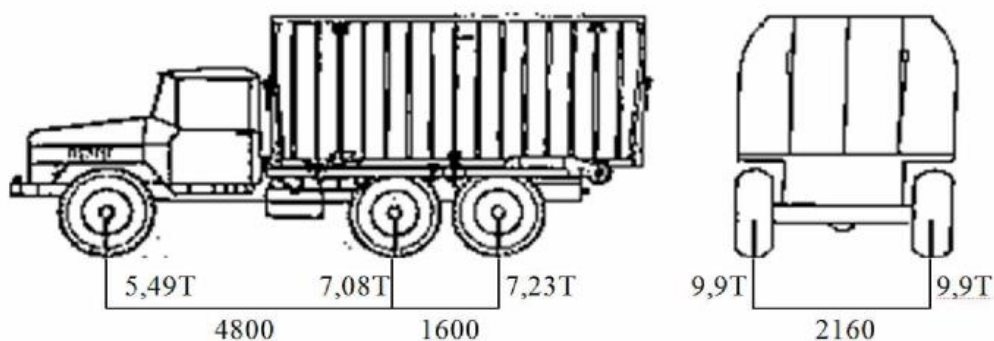


Figure 3. Truck with tires Kraz.

For the purpose of improving the safety factor, in the calculation, according [7, 8], the load factor  $\gamma_1 = 1.25$  for static load itself;  $\gamma_2 = 1.75$  for the live load of the vehicle, the shock coefficient due to the impact of the vehicle over the bridge  $1 + IM = 1.25$ .

The grating plate directly receives the wheel load and transmits it to the crossbeam. The contact area of the wheel with the grating plate is rectangular, with the following dimensions [7]: Width equal to wheel width, for trucks, take  $B_{lx} = B_{bx} = 0.5$  m, and contact area length is equal to  $L_{lx} = 0.4$  m. Thus, it can be considered that the load P of the axle is transmitted to the grating plate through an area of:

$$F_{lx} = B_{lx} \cdot L_{lx} = 0.5 \cdot 0.4 = 0.2 \text{ m}^2$$

Due to the scope of the article, and going into the calculation of the deck slab from the grating plate, while the cross beam and main truss are taken according to the size of the existing Bailey bridge, there is no need to check the bearing capacity of the cross beam and master rig again. The bearing bars and cross bars of the grating plate are linked to each other, the connection between the deck modules and the horizontal beams is a joint connection (the bridge deck module rests on the transverse beam). The problem being investigated is a simple span girder problem, so the most unfavorable position is to load the heaviest wheel axle in the middle of the bridge, in the middle of

the deck plate will give the largest internal force result. The author uses SAP2000 software to model and calculate [9, 10]. Below are some illustrations:

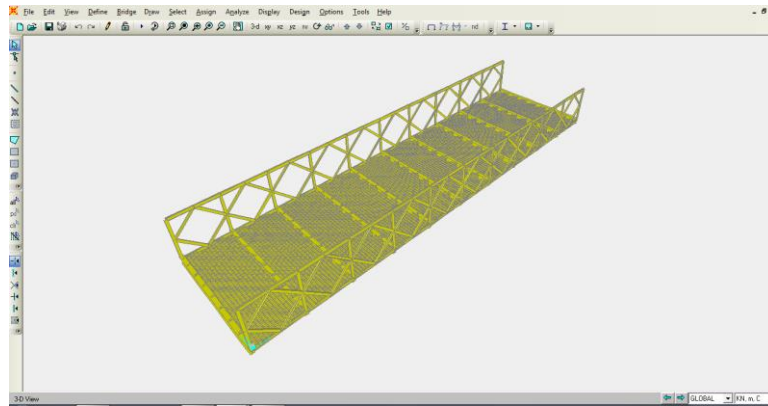


Figure 4. Bailey bridge model has a grating plate.

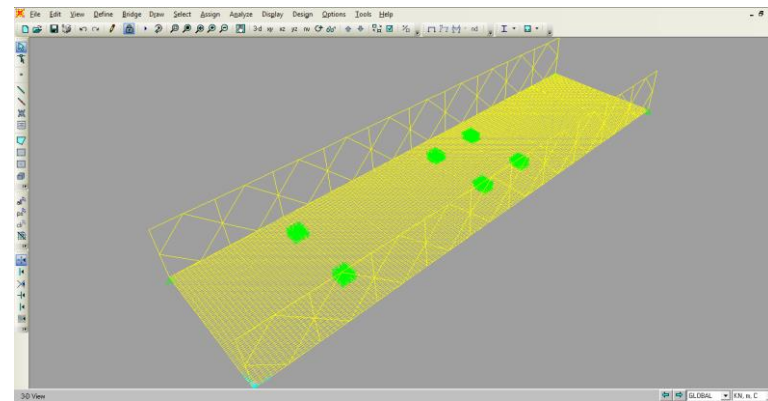


Figure 5. Load declaration.

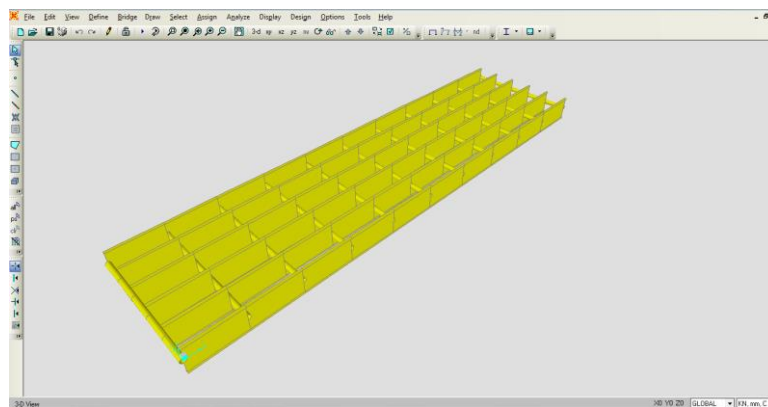


Figure 6. Model of a grating plate on software.

When declaring the load, because the wheel load is evenly distributed over an area of size  $B \times H$ , when modeling, consider this load to be transmitted at the intersections

between the bearing bar and the cross bar, these nodes are within the limit  $B \times H$ , these forces are concentrated forces and have a main sum equal to the load  $P$  of the wheel.

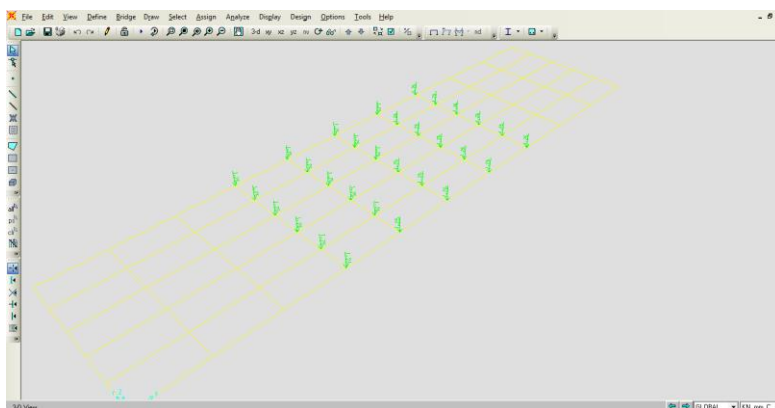


Figure 7. Declaration of the load on the grating plate.

### 3.2. Survey results

From the above model, when the deck slab is subjected to vehicle load, we get the result for the internal force of a bearing bar of grating plate as shown in Table 2.

Table 2. The results of the calculation of internal forces appear in the grating plate

Frame	Output case	P	V2	V3	T	M2	M3
Text	Text	kN	kN	kN	kN-m	kN-m	kN-m
29271	1.25*TTBT +1.75*HTX	-0.105	-0.072	-0.017	0.0087	-0.00085	1.0606

Since the load capacity of the bearing bar is mainly regulated by the bending moment, the author conducts a test of the bending resistance of the bearing bar. According to [7], the bearing bar has sufficient bearing capacity when satisfying the condition of bending resistance:

$$M_u \leq \phi_r \cdot M_n \quad (1)$$

where  $M_u$  is the moment caused by the load, according to the above calculation results  $M_u = 1.0606$  kN.m;  $M_n$  is the nominal bending resistance of the bar,  $M_n = F_y \cdot Z_x$  where  $F_y$  is the yield strength of the steel material,  $Z_x$  is the static moment of the section. The static moment value of a bearing bar of grating plate with cross section  $6 \times 70$  mm ( $b \times h$ ) is:

$$Z_x = \frac{b \cdot h^2}{6} = \frac{0.006 \cdot 0.07^2}{6} = 4.9 \cdot 10^{-6} \text{ m}^3$$

$\phi_r$  is the coefficient of resistance to bending, according to [7] then  $\phi_r = 1$ . Substituting the above values into expression (1) we have:

$$1.0606 \leq 1 \cdot F_y \cdot 4.9 \cdot 10^{-6}$$

From there we get:

$$216(\text{MPa}) \leq F_y \tag{2}$$

Currently, according to Vietnamese standards [11], the yield strength  $F_y$  of steel used in the structure is about 220 MPa or more depending on the type of steel as shown in the table 3 below. In addition, in the market, there are some imported steels according to foreign standards with yield strength of 250 MPa or more such as A36 [12], even high-strength steel with yield strength of more than 300 MPa such as ASTM A709/Gr345.

Table 3. The yield value of some steels according to TCVN 5709:2009

Steel Grade	Yield strength $F_y$ , MPa for thicknesses up to 20 mm, not less than
CXT 34	220
CXT 38	240
CXT 42	260
CXT 52	360

Thus, CXT 34 steel with yield strength value  $F_y \geq 220$  MPa can be selected as the material for the selected grating plate, or CXT 34 steel with  $F_y \geq 240$  [11], or A36 steel with  $F_y \geq 250$  MPa [12], or other high strength steel to satisfy the condition (2).

With the above calculation results, it is found that it is possible to choose the type of grating plate material to satisfy the condition that the bending moment caused by the load is smaller than the resistance of the bearing bar, so the grating plate has the same size as the example above (bearing bar with cross section  $6 \times 70$  mm, spaced 80 mm apart) made from CXT 34 steel material with  $F_y \geq 220$  MPa or other steel material with  $F_y$  more, capable of bearing the load of 20 tons (or 196.13 kN) trucks.

The above theoretical calculation is the initial basis to confirm that the grating plate can be used as a bridge deck to replace longitudinal beams and horizontal wooden planks in the quick-assembled bridge Bailey for national defense and security purposes, as well as rescue tasks under the load of vehicles.

#### 4. Conclusion

Through the study to determine the bearing capacity of the bridge deck assembled from the grating plates as above when subjected to the load of the wheeled truck, it was found that the ability to use the grating plate as the bridge deck is completely feasible. For example, a grating plate consists of a bearing bar with a cross section of 6×70 mm, spaced 80 mm apart, a cross bar made of round steel with a diameter of 10 mm, the distance between them 150 mm, CXT34 steel material with a  $F_y$  of 220 MPa or more capable of bearing the load of truck with 20 tons (or 196.13 kN) tires. The above theoretical calculation is the initial basis to confirm that the plan of the deck slab from this grating plate can be applied in practice.

Due to the limited scope of the article, in addition to the problem of calculating the bearing capacity through the flexural strength parameter mentioned above, the author has not gone into the calculation and solved many other problems when studying the structural bridge deck from plate grating such as the problem of optimizing the grating structure, the bearing capacity of the grating when bearing the load of the crawler, testing on a real model,... The author hopes to be able to discuss these issues with colleagues and readers for further improvement.

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## NGHIÊN CỨU KHẢ NĂNG ỨNG DỤNG TẤM GRATING LÀM BẢN MẶT CẦU TRONG CẦU LẮP GHÉP NHANH BAILEY

**Nguyễn Mạnh Thường<sup>a</sup>**

<sup>a</sup>*Trường Đại học Kỹ thuật Lê Quý Đôn*

**Tóm tắt:** Bài báo trình bày việc tính toán sức chịu tải của bản mặt cầu trọng lượng nhẹ được ghép từ các tấm grating. Tác giả sử dụng phần mềm SAP2000 trên cơ sở phương pháp phần tử hữu hạn để kiểm tra cường độ và độ võng của bản mặt cầu này khi chịu tải trọng xe quân sự bánh lốp. Từ đó rút ra kết luận nhằm xây dựng cơ sở khoa học xác định khả năng sử dụng tấm grating làm bản mặt cầu dùng cho các cầu lắp ghép nhanh phục vụ nhiệm vụ an ninh quốc phòng, cứu hộ cứu nạn.

**Từ khóa:** Tấm grating; bản mặt cầu; cầu lắp ghép Bailey; sức chịu tải; xe tải.

*Received: 10/04/2023; Revised: 18/05/2023; Accepted: 23/06/2023; Published: 30/06/2023*

