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Model Test Prestressed Steel Truss Bridge With Composite Floor

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ABSTRACT
This paper presents the result of research on the composite pre-stressed steel truss for the typical steel truss bridge with deck above. Pre-stressing was carried out by installing tendon / pre-stressed cable at lower part of the truss, connected to their anchorages which are installed at both ends. The composite action of the structure was obtained by connecting the reinforced concrete deck and top chords of the truss using bolts which functioned as shear connectors. To understand the serviceability thereof, a loading test was conducted to the structure with and without shear connectors. A digital mechanical of loading test was used for this purpose. It yielded that the serviceability of the composite pre-stressed steel truss was 71% bigger than that of non-composite.
KEY WORDS : *Tendons, prestress, anchors, composite, shear connector.*

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I INTRODUCTION

1.1 Background

A steel truss bridge is a typical structure among the transport infrastructure means which provides passage over the hurdles including river, valley, strait, or other structures underneath.

The usage of prestressed concrete has been growing, but it is difficult to erect in the remote areas for lacking of access roads for the purpose of transporting heavy equipments for girder installation. To overcome this condition, a composite prestressed steel truss is introduced to replace the prestressed concrete for the bridge. The former can be manufactured in the plant with knockdown system, so it can be brought with small-sized vehicles, assembled at site easily, and erected with simple tools. The steel truss bridge with concrete deck to bear live load thereon is still commonly used where the steel truss is at the top of the concrete floor. As such, the steel and concrete floor are non-composite. It is therefore necessary to study the bridge structure with the streel truss at the lower part of the concrete deck which is called ”composite”. The concrete floor acts to resist against compressive force and the steel truss to resist against tension force. More over, if the steel truss is pretressed, the prestressed cables bear the tension force.. This structure is called Prestressed Composite Truss. The steel truss only functions to carry concrete floor, and the live load generated will be borne by reaction of cable tension and compression of concrete floor. With this concept, dimensions of the steel truss and concrete floor will be more economical, so the total weight of the bridge will be much reduced.

1.2 Objectives

To examine the performance of the composite action of the bridge model and to determine the increase of the serviceability obtained from the composite action between the concrete floor and prestressed steel truss..

1.3 Benefits

It is expected that this bridge model can be applied in the field and provides a solution of producing light and strong bridge.

II LITERATURE REVIEW

2.1 Basic theory

The prestressed composite steel truss bridge is a bridge with the main structure of reinforced steel truss with external prestressing cables. Such a structure will be composed with reinforced concrete deck. The idea stemmed from the theory of gerberr reinforced beam comprising hanging and supporting structures (F.KH Yap, 1997) and the study of reinforced steel beams using trekstang (Honing, J, 1996), as well as the study of Externally Concrete Slab Bridge: Model Test Result. (Naaman A, 1990).

2.2 Reinforcement of truss

The basic concept of reinforcement of the truss is that to produce the steel truss structure with the same dimensions whh is able to bear a larger load. This can be done in by: provide load balancing to external loads by placing the parabolic tendon to the structure that has been stretched (Nawi EG, 1996). According to the Engineering Statics (RC Hibbeler, 1997), a load P can be obtained with the following analysis :

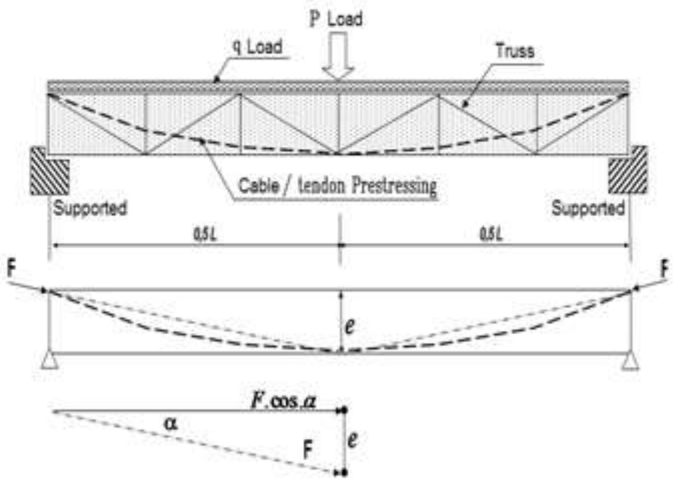


Figure 1. Derivation of the formula of load P

M internal = $^1/_8\, q\, L^2 + ¼\, P\, L$
M external = $F\ Cos\ \alpha\ .\ e$

$$\sigma tk // = \frac{F.\cos.\alpha}{A} \Rightarrow F.\cos.\alpha = \sigma tk // .A$$

A = cross-sectional area top chord of a truss
M internal = $\sigma\ tk//\ .\ A\ .\ e$
Provided : M internal = M external
$\Rightarrow\ \sigma\ tk//\ .\ A.\ e\ = {}^1/_8\, q\, L^2 + ¼\, P\, L$

$$\text{then } P = \frac{\sigma_{tk} // .A.e - \frac{1}{8}.q.L^2}{\frac{1}{4}.L}$$

The dimension of the cable / tendon can be calculated as follows :

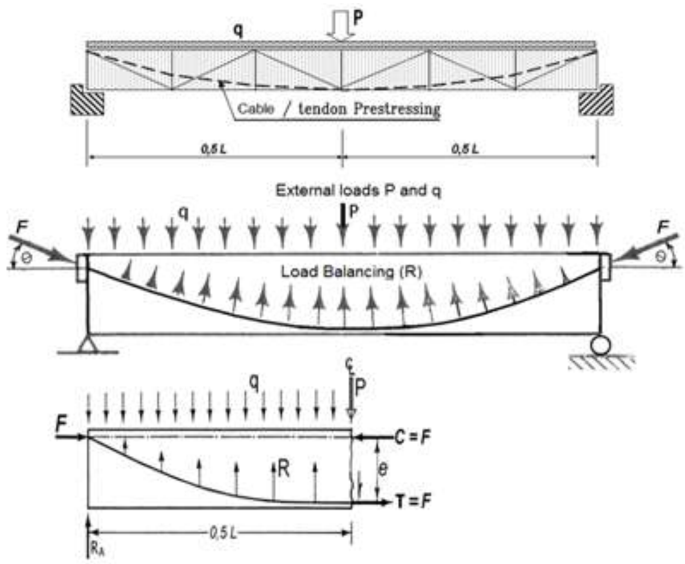


Figure 2. Derivation of the formula of T Force

Moment internal $= \frac{1}{8}.q.l^2 + \frac{1}{4}.P.l$

Moment ecternal (Mi) = T x e

Moment external = Momen internal

$$\tfrac{1}{8}.q.l^2 + \tfrac{1}{4}.P.l = T.e \Rightarrow maka, T = \frac{\frac{1}{8}.q.l^2 + \frac{1}{4}.P.l}{e}$$

Cable diameter (D) $= \sqrt{1,27 \frac{T}{\sigma_a \text{ kabel}}}$

The dimension of the tendon/cable has been found.

2.3 **Composite structures**

The regulations on highway bridges with composite structures have been issued by AASHTO. In this bridge concept, the longitudinal shear force is transferred from the steel beams to the reinforced concrete slab using shear connectors (shear connector), this has resulted in the concrete slab to bear the bending moment (Setiawan, Agus 2008).

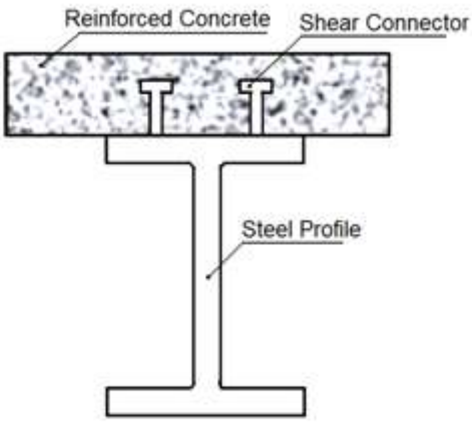


Figure 3. Composite Steel with Concrete

To be able to calculate the stresses in a composite section, it is necessary to transform the cross section of concrete to steel. Figure (4) shows a segment of a composite beam with stress and strain diagrams.

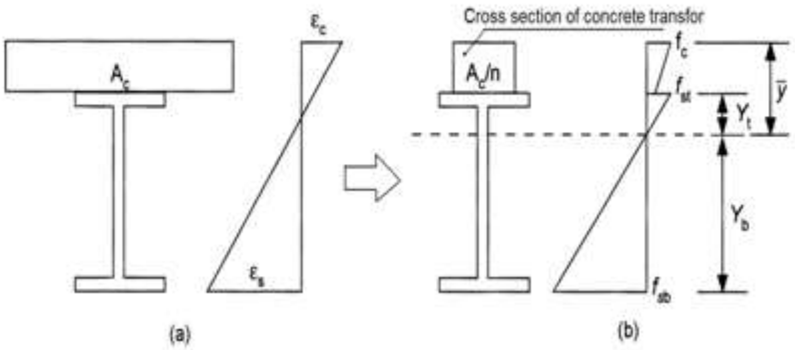


Figure 4. The diagram of stress and strain of composite structure.

To transform the concrete area (Ac), the effective width of the concrete slab can be divided by n, while thick of concrete does not need to be changed. To calculate the stress, then it must first calculate the location of the neutral axis and the moment of inertia of the cross section. Then it calculates the bending moment at the top and bottom of steel profiles, using the following equations :

$f_{st} = M . y_t / I_{tr}$

$f_{sb} = M . y_b / I_{tr}$

Where:

M = is the bending moment

Itr = is the moment of inertia

yt = is the perpendicular distance from the neutral axis to the top fiber of steel profile.
yb = is the perpendicular distance from the neutral axis of the bottom fiber of steel profile.
n = Es / Ec

The stress on the fiber concrete is calculated based on the equation:

$$f_c = \frac{M.y}{n.I_{tr}}$$

The deflection occured due to live loads on concrete composite stell will result in a slip between the concrete with the flange of the profile. This slippage was caused by the presence of shear forces generated from the deflection of concrete and steel (Nie Jianguo, 2003)

$$P.\tau = K.S$$

Where $P =$ distance between shear connectors

$\tau =$ shear stress

$K =$ Shear stiffness of shear connectors

$S =$ slip between the steel with concrete

Shear forces that occur between the concrete slab and steel profiles must be borne by a number of shear connectors, so there is no slip at the serviceability loads. The horizontal shear force that must be borne by the shear connectors is stipulated in SNI 03-1729-2002 Article 12.6.2. :

$A_s . f_y . 0,85 . f'_c . A_c$ or $\sum Q_n$.

$Q_n = 0,5 . A_{sc} \sqrt{(f'_c . E_c)} \leq A_{sc} . f_u$

Where: Asc = cross-sectional area of stud shear connectors, mm^2

fu = tensile of stud shear connectors, MPa

Qn = nominal shear strength for shear connectors

2.4 **Prototype of Composite Prestressed Truss Bridge**

The prototype of bridge model is pre-stressed steel truss with parabolic tendon trace. The pre-stressed steel truss was composed with reinforced concrete above that serves as a bridge floor. In order for the concrete and reinforced steel to be composed, then shear connectors should be installed, so that the composite action may occur. The combined structure is called "Prestressed Composite Truss

III METHODOLOGY

To accomplish the goal, the following actions have been taken :

a. Make a model of prestressed composite steel truss bridge with a length of 4 m and a width of 0,9 m floor.

b. Perform testing of the bridge model with static load test gradually until it has achieved the maximum deflection of 0.5 cm, or the maximum load limit of 500 kg.

c. Conduct an analysis of the performance of the bridge by comparing the deflection occured to the structure before and after the composite action

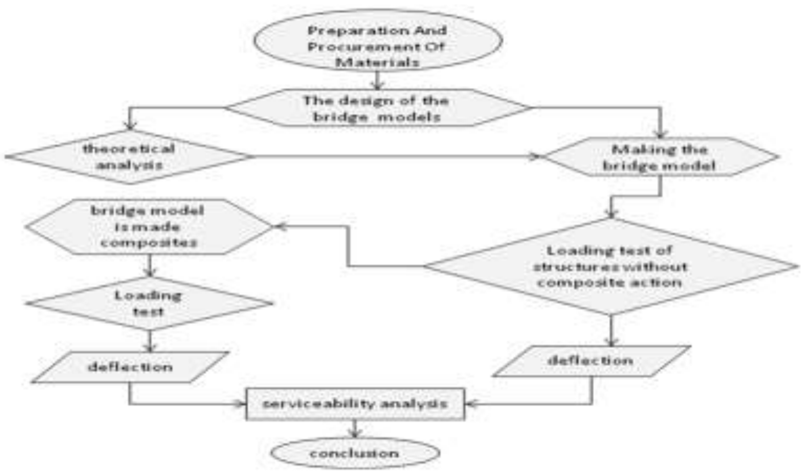


Figure 5. Flow diagram of research

3.1 **Testing Method**
To figure out the performance of the structure, it is then tested according to the following steps:

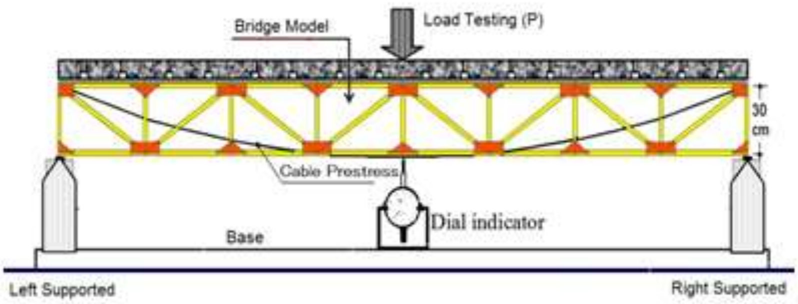


Figure 6. The method of testing

Steps :
1. Install the loading test equipment.
2. Install supports for bridge model
3. Install the bridge model without shear connector at each support
4. Install a dial indicator at the dial stand.
5. Perform testing with gradual loading on the bridge model. Tests shall be conducted in two conditions, loading and unloading.
6. Record the test results
7. Remove the loads
8. Install shear connector in pre-stressed truss
9. Tighten pre-stressed cable.
10. Measure and record camber took place because of pre-stressing.
11. Conduct re-loading test
12. Re-read dial readings.
13. Tabulate the results of the loading test.

3.2 **Data Analysis**
Data analysis was done by means of comparing
the results of the loading test performed on composite and non composite structure to determine the serviceabilty of the structure because of the composite action of the structure.

IV RESULTS AND DISCUSSIONS

4.1 **Prototype**

The bridge model used the steel double angled profile 21.5x21.5x1.7mm. The cable is braided wires with a diameter of 3 mm. The reinforced concrete deck has a thickness of 4,5 cm.

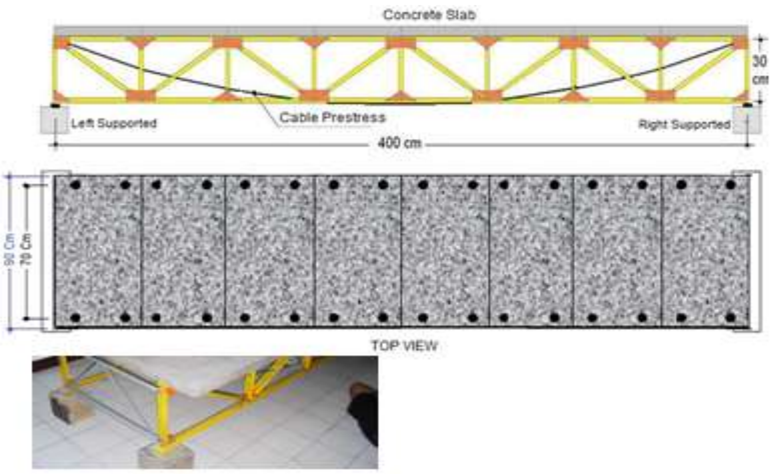


Figure 7. Bridge Prototype

4.2 Loading Test Instrument

The loading test instrument used is the "Digital Mechanical Loading Test" with a capacity of 500 kg. This tool is equipped with a lever actuated manually to adjust the pressure on the "load cell" through the jack suppressant. The compressive force detected by the "load cell" can be seen on the screen "digital load display".

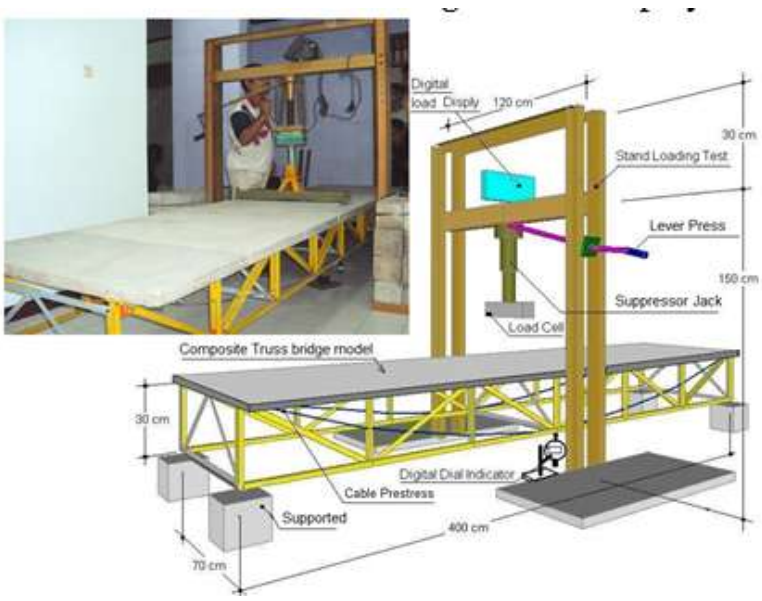


Figure 8. Loading Test Equipment

4.3 Loading Test

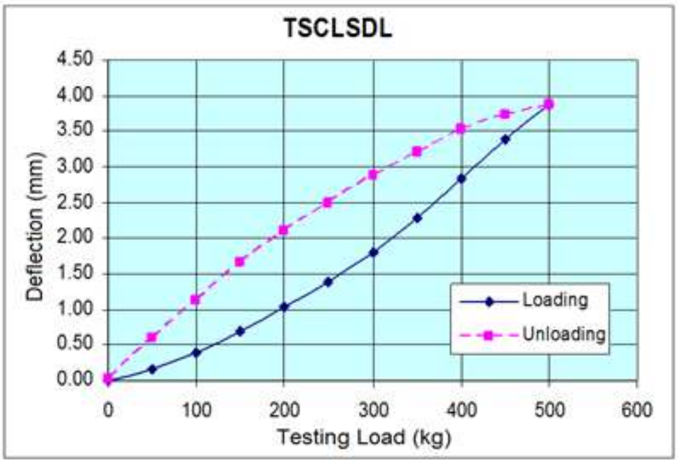
Figure 9. Loading Test

The loading test was conducted to determine the deflection of structure that receives lateral load, at the condition before and after the composite action. The load testing is gradually increasing from 0 to 500 kg.

4.4 Testing Results

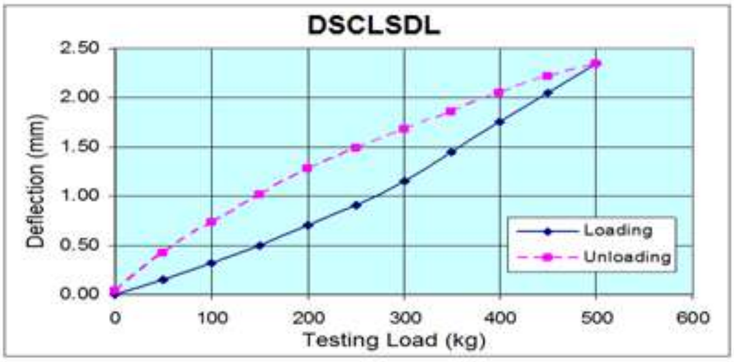
a. Loading Test Structure

The summary of test result data loading on pre-stressed composite truss structure is presented in the diagram below.



TSCLSDL (Without shear connector and the floor has glue)

Figure 10. Results of test structures without shear connector.



DSCLSDL = The shear connector and the floor has been glued.

Figure 11. Results of test structures with shear connector.

b. Composite Action Performance

To determine the performance of the structure with shear connector, a comparison between the deflection test results with and without shear connector installed in the structure.

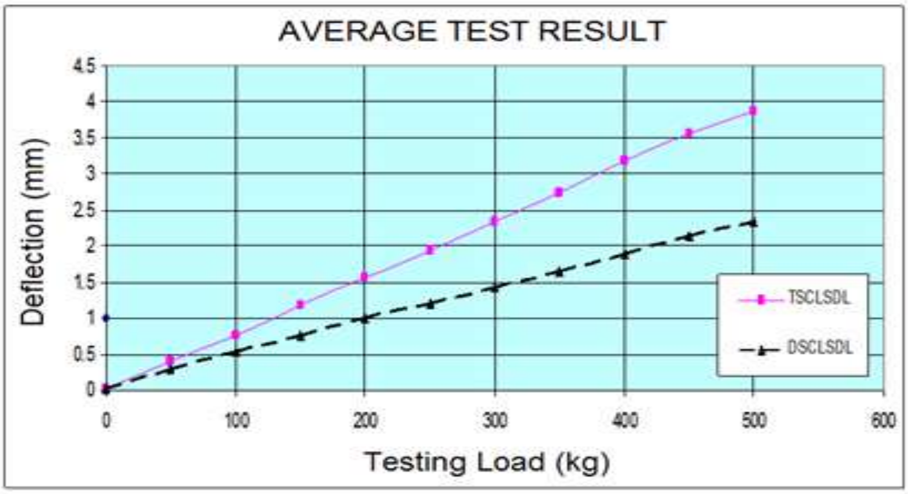


Figure 12. The comparison of test results without shear connector and with shear connector.

The diagram above shows that the structure with shear connector was able to bear greater loads than that of without shear connector.

c. Improvement of Serviceability

To determine the serviceability of the structure that was contributed by the presence of shear connector, a trend line analysis of the chart loading test results was performed. The said trend line is then used to find the load that is capable of being borne by the structure at a certain maximum deflection of 2.3 mm. The magnitude of serviceability is determined by comparison of the ability to withstand the load with the same deflection of the two types of structures.

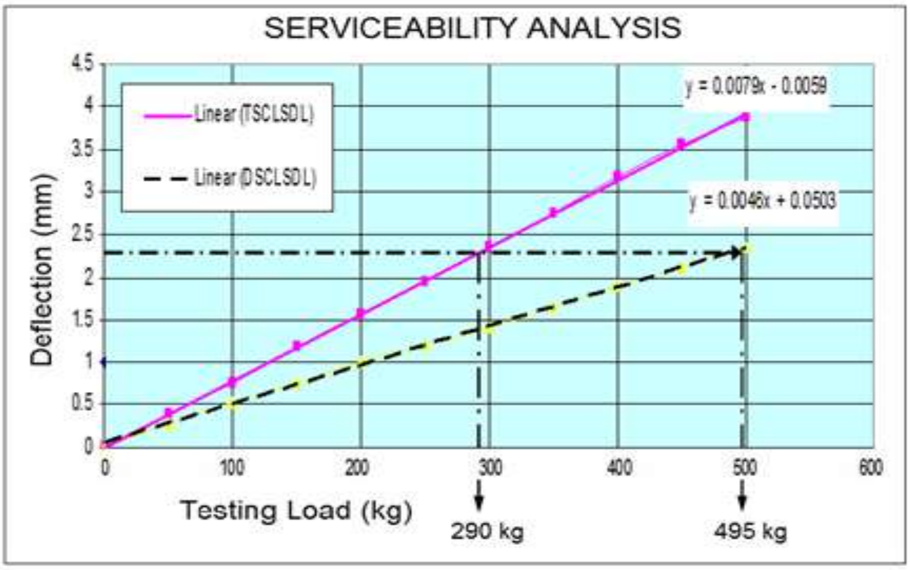


Figure 13. serviceability analysis.

In the above analysis shows that the deflection of 2.3 mm, with shear connector structure capable of withstanding a load of 495 kg, while the structure without shear connector is only capable of withstanding a load of 290 kg. This means that the presence of shear connector makes structure stronger. Improved serviceability power obtained was ((495-290) / 290) x100% = 71%. So with the shear connector, the structural strength has increased by 1.71 times.

V CONCLUSION

The shear connector linking the the reinforced concrete of floor bridge with the top of pre-stressed truss structure shall be able to increase the serviceability of the structure by 71%, or in the presence of composite action between the pre-stressed steel truss and bridge deck, structural strength has increased by 1.71 times of its original strength.

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