e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

Sustainable Solution for Shoring Method of Cross-Creek Bridge in Ankeng MRT System in New Taipei City: A Case Study

Tai-Yi Liu [1], Cheng-An Lee[2], Hong-Kee Tzou[3], Shiun-Jye Lin[4], Mao-Yi Chou[5] and Ke-Fan Jhan[6]
[1]Chief Engineer, New Asia Construction and Development Corporation, Taiwan, REPUBLIC OF CHINA
[2]Director, Department of Rapid Transit Systems, New Taipei City, Taiwan, REPUBLIC OF CHINA
[3]Chairman, New Asia Construction and Development Corporation, Taiwan, REPUBLIC OF CHINA
[4]Deputy Director, First District Project Office, Department of Taipei MRT system, Taiwan, REPUBLIC OF CHINA
[5]Project Manager, Department of Rapid Transit Systems, New Taipei City, Taiwan, REPUBLIC OF CHINA
[6]Leader Engineer, New Asia Construction and Development Corporation, Taiwan, REPUBLIC OF CHINA

[1]Corresponding Author: tylaytpe@ms9.hinet.net

ABSTRACT

In the Ankeng Light Rail MRT system (ALRMS) project, the U7 box girder passes crossing the Erbads creek and needs a temporary supporting system for the construction work. In this study, three temporary shoring system options were proposed to be the construction method. The D-B Contractor, New Asia construction and Development Corporation, evaluated and selected the optimal choice, The Steel truss frame with supporting beams, to serve as the temporary supporting system. Compare the deflection of Δ_{max} and Δ_{actual}, which are 1.609 cm and 1.59 cm, respectively. This result presented that the shoring system composed of the H912*302*18*37 supporting beams and steel truss frame had achieved outstanding performance and work to construct the U7 box girder. This paper presents how the three options are evaluated and the detailed construction processes along with the survey verification for the method.

***Keywords*—** Ankeng Light Rail MRT System (ALRMS), Sustainable Solution, Shoring Method, U7box Girder, Erbads Creek

I. INTRODUCTION

The global warming condition has caused some extreme impact on the environment and human life. Recently, in the world, the “sustainability” issues for the lifecycle of infrastructures are more and more concerned and discussed during the development of the projects. Specifically, “green” civil projects are being emphasized through designs and constructions that support long-term sustainability. In Taiwan and globally, the “green building” assessment systems had been well established and applied for the development of building projects. It is a regulation to use the EEWH assessment system for public building projects [1-8]. However, the sustainability assessment system for green civil infrastructure (SASGCI) had been only a few research focused on this critical issue [9]. For sustainability development, the four stages of the whole lifecycle, including design, construction, operation, and demolition, of an infrastructure project should be taken into consideration [9]. In this paper, the authors would like to share the experience on the determination of the temporary shoring system for the cast-in-place box girder of a cross-creek bridge of the Ankeng Light Rail MRT system (ALRMS) in New Taipei City

The ALRMS is a 7.5 km length project, includes nine stations. It contains four grounded stations, and five elevated stations, respectively [10,11]. The client of the ALRMS is the Department of Rapid Transit Systems (DRTS), New Taipei City. The main D-B Contractor is the New Asia Construction and Development Corporation (NACDC). The project construction management (PCM) and the site supervising are performed by the Sino-Tech Consultant Company (STCC) and MAA Group, respectively. Figure 1 shows the route map of the ALRMS.

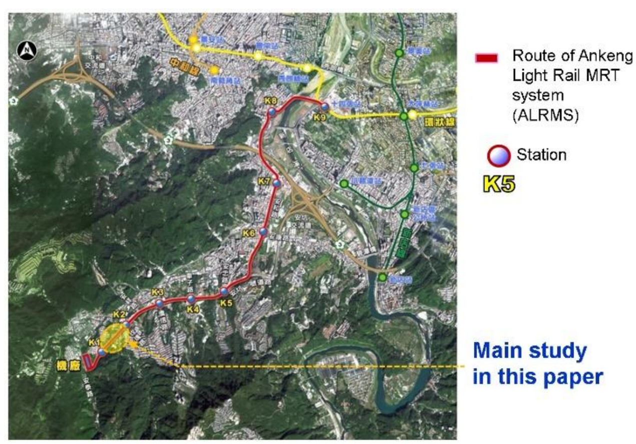

Figure 1: The route map of the ALRMS

There are three major types of bridges that are designed in the ALRMS project, which are listed as follows:

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
www.ijemr.net
https://doi.org/10.31033/ijemr.11.1.3

- Temporarily supported cast-in-place bridges by shoring system.
- Free Cantilever Method (FCM) bridges by the movable truss system.
- Steel trusses or steel boxes bridges [11].

The authors focus on one of the temporarily supported cast-in-place bridges, numbered as U7 unit, which needs to cross the existing creek named Erbads Creek. This Erbads Creek width is approximately 12m in width and 1m in depth. The temporary shoring system for the U7 unit is quite different from the other cast-in-place bridges due to the water flow needing to be maintained during the bridge's construction. Some proposed options, including the consideration of sustainability issues, were discussed during the construction stage. The detailed determination processes are presented in the following sections.

In this paper, the authors focus on the detailed problem description, optional method discussion, and solution determination. Figure 2 shows the research framework for this study.

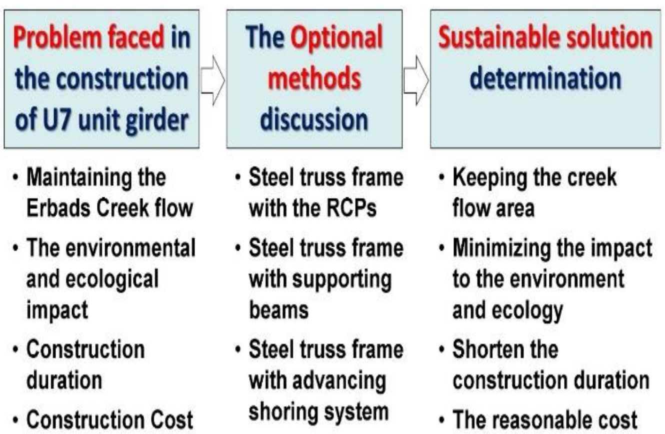

Figure 2: The research framework for this study

II. PROBLEM FACED IN THIS STUDY

One of the cast-in-place bridge between the K1 and K2 stations, which includes six units of superstructure box girders (U6 to U11), two abutments (A4-1 and A4-2), and five piers (P4-1to P4-5). The Erbads creek flow through the U7 unit, which is located between the P4-1 and P4-2 piers, with a width of 12m and depth of 3m. In the storm season, the width could be increased up to 20m, and the depth increased up to 2~3m. It is quite a challenge to the construction of a cast-in-place bridge. Figure 3 shows the plan and vertical views of the zones nearby the U7 unit.

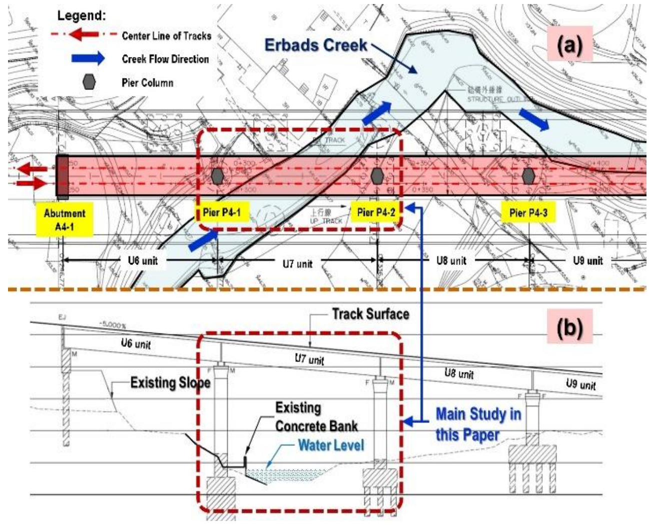

Figure 3: The U7 unit drawings: (a) plan view and (b) vertical view

To maintain the Erbads creek flow, it is necessary to install a reliable and safe shoring system for the construction of the U7 box girder. A couple of temporary shoring options were taken into considered and discussed when the engineers determine the methods. Not only the safety, working duration, cost, materials, and installation difficulty, of the shoring system were considered for determination; the environmental and ecology issue was also the essential factors for engineers' consideration.

III. CONSTRUCTION OPTIONSS DISCUSSION

There are three types of temporary shoring options, which are considered and discussed in this study. The discussion includes all possible influence factors for the U7unit construction.

3.1 Option 1: Steel Truss Frame with the RCPs

This option contains some soil filling work in the creek reservation zone. Figure 4 shows the shoring system for this option. In this option, the center steel truss frame is supported by the soil filling. Several Reinforced Concrete Pipes (RCP) must be embedded into the filled soil to maintain the creek water flow, as shown in Figure 4. The total cross-section of the RCPs must be sufficient for the peak water flow. The strength of the RCPs might not be able to resist the heavy loads, which are transferred from the superstructure. Thus, a protection RC slab should be placed to be the bearing of the steel truss frame. Furthermore, the compaction for the filled soil should be very compacted

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

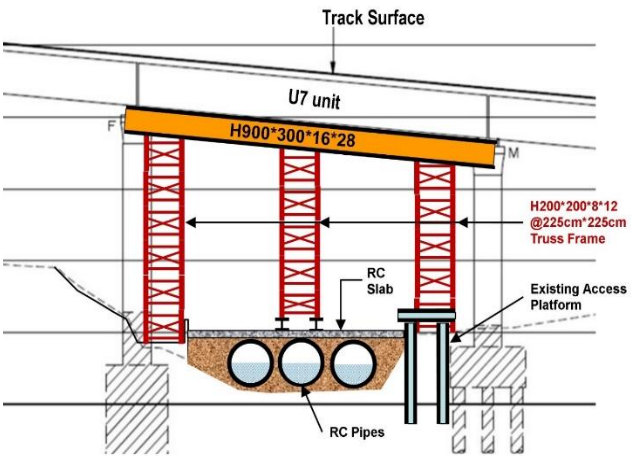

Figure 4: The shoring system of steel truss frame with the RCPs

As shown in Figure 4, this option includes the following processes:

a. Temporary diversion of the creek water flow of the Erbads creek.
b. Smoothening work for the river bed and needed aggregate pavement.
c. RCPs installation and connection. The RCP diameter is calculated to be 1.5m, and the total length needed approximately to be 90 m.
d. Soil filling and compaction. It is calculated to be 900 m^3.
e. Protection RC slab placement with a thickness of 30 cm.
f. Guidance of the water flow to the RCPs.
g. Installation of the steel truss frame and U7 box girderr construction.
h. Removal of steel truss frame, RCPs, and the filled soil.

In this option, the water flow route of Erbads creek is needed to be temporarily changed. It might cause some environmental and ecological impact on the creek. Also, the strength of the RCPs should be special care due to the heavy load of the steel truss frame transferred from the U7 box girder.

Figure 5 shows the typical site installation of RCPs.

Figure 5: The typical site installation of RCPs

3.2 Option 2: Steel Truss Frame with Supporting Beams

To prevent the Erbads creek impact as mentioned in the previous option, this option uses temporary supporting beams instead of RCPs and soil filling. Figure 6 shows the assembly of option 2.

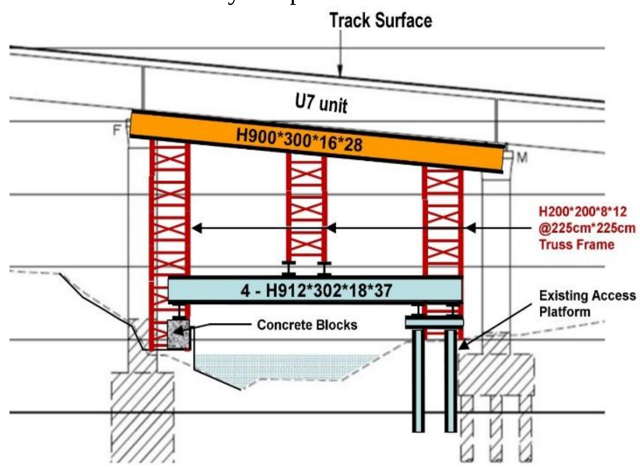

Figure 6: The shoring system of steel truss frame with supporting beams

There is an existing steel access platform located neighborly to the Erbads creek. It is a functional device for the shoring system. The following working processes are included in this option:

a. Concrete blocks stacking with the H400*400*13*21 steel beams installation.
b. Erection of H912*302*18*37 supporting beams m. A total of four beams needs to be installed with a length of 14 m.
c. Installation of the steel truss frame and U7 box girder construction.
d. Removal of steel truss frame and the supporting beams.

In this option, the water flow of Erbads creek could be maintained and kept in the original water reservation zone. Figure 7 shows the typical site installation of the steel truss frame.

Figure 7: The typical site installation of the steel truss frame

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

3.3 Option 3: Steel Truss Frame with Advancing Shoring System

The features of option 3 are similar to option 2. There is no construction work in the creek reservation zone. Figure 8 shows the assembly of option 3.

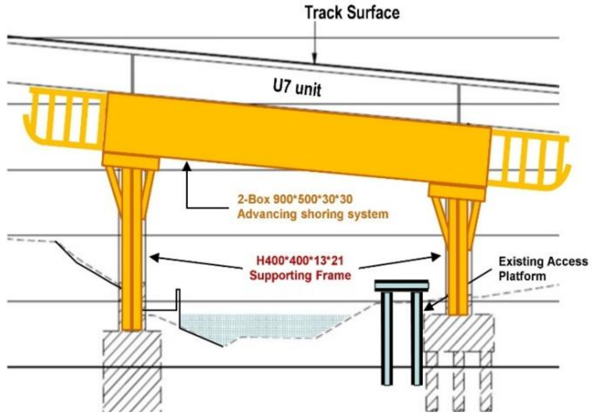

Figure 8: The shoring system of steel truss frame with advancing shoring system

Instead of the center parts of the steel truss frame and the supporting beams, this option uses the advancing shoring system. to be the prime scaffolding system for the construction of the U7 box girder. The main work includes:

a. Installation of the steel truss frame at the location of the piers No. P4-1 and P4-2.
b. Erection of advancing shoring truss system.
c. Construction of U7 box girder.
d. Removal of the dvancing shoring truss system.

The Erbads creek water flow will also be not influenced during the construction of this option. But since the dvancing shoring truss system is quite a heavy-duty advice for superstructure construction, the duration of the system erection will be much longer, and the cost will be significantly increased. Figure 9 shows the typical site assembly of the advancing shoring system

Figure 9: The typical site assembly of the advancing shoring system

IV. DETERMINATION AND SELECTION FOR THE CONSTRUCTION METHOD

For evaluation and determination on the above stated three options, the most critical issues are compared and discussed, as shown in table 1. In Table 1, each evaluation is marked as 1 to 5 points. Higher points represent high performance for evaluation. The total points obtained by the summation of each evaluation item and listed in the “Summarization” row of Table 1. The highest calculation result is the final determination for the selection of structure type for the SDPs design and construction.

Table 1: Comparison table for the three options of Temporary Shoring System

Evaluation items	**Option 1**	**Option 2**	**Option 3**
Safety and risk mitigation	2	5	5
Reliability	3	5	5
Environment protection	4	4	4
Ecological conservation	3	5	5
Durability	4	5	5
Landscape	4	3	3
Construction Duration	3	5	3
Cost	4	5	3
Humanity	4	3	3
Creatibility	3	3	3
Summarization	**34**	**43**	**39**

The results are shown in Table 1 that indicates option 2: the shoring system of steel truss frame with supporting beams, which is evaluated to be**43 points**, is the highest score in the comparison. In other words, option 2 is the most reliable, sustainable, and environmentally friendly selection for the construction of the U7 box girder.

The construction procedures are quite simple and much less than option1 and option 3, which are mentioned above. The benefits of option 2 are summarized as follows

1. Reliability and safety on shoring strength

The H912*302*18*37 supporting beams provide high strength for the loads transferred from the U7 box girder.

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

2. Economic Benefit

It is more economical in terms of both material and labor in comparison with other alternatives. It also presents a lower cost than the alternatives.

3. Ecological and Environmental-Friendly

The steel beams achieve the recyclable feature. The prevention of soil filling in the water reservation zone avoids any impact on the Erbads creek.

4. Shortening the Duration

The minimized erection duration for the steel beams leads to the shortest duration for the U7 box girder construction.

5. Carbon Emission Reduction

The minimizing of equipment operation hours and shortening of construction duration present the carbon emission reduction efficiency. Table 2 shown the total reduction of the carbon emission compares to the other options. As shown in Table 2, this option leads to a 23.5 tons carbon emission reduction.

Table 2: The Total Reduction of the Carbon Emission Compare to the Other Option

No	Items	Unit	Total reduced quantity	Carbon emission factor	Carbon reduction (kg)
1	Truck	Set-day	252	1.29	325
2	Transportation	km	5,612	0.24	1,346
3	Diesel Fuel	L	3,920	3.45	13,524
4	Gas fuel	L	2,613	3.11	8,126
5	Power	Hrs.	240	0.85	204
	Total				**23,525**

V. CONSTRUCTION AND LOADING CALAULATION

After a detailed evaluation and comparison of the proposed three construction options for the U7 box girder, option 2: the shoring system of steel truss frame with supporting beams, was selected to serve as the most sustainable method. The NACDC engineers established the working plan [12, 13] to be the construction guidance of the U7 box girder's shoring system. The installation of this shoring system follows the working plan, with the supervision and inspection of the corresponding author, Dr. Liu. Figures 10 and 11 show the shoring system's site photos and the inspection of the supporting beams by the corresponding author with the client engineers.

Figure 10: The site photos of the temporary shoring system

Figure 11: The inspection of the supporting beams by the corresponding author with the client engineers

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

Furthermore, the deflection of the steel supporting beams is one of the critical factors to influence the value of camber for the U7 box girder. Thus, the engineers carefully calculated the maximum deflection of the steel supporting beams well to control the U7's camber value [14, 15]

The H912*302*18*37 steel supporting beams are the critical factor of success for this shoring system. Figure 12 shows the basic physical parameters of the H912*302*18*37 steel supporting beam.

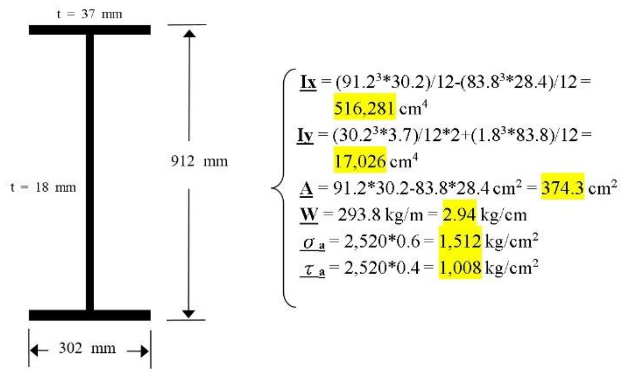

Figure 12: The basic physical parameters of H912*302*18*37 steel supporting beam

In this study, the maximum superstructure loads transferred from the steel truss frame is P = 59.2 tons. The M could be calculated by adopting the equation (b):

$\boldsymbol{M = P*L/4 + W*L^2/8}$ ………………………..(a)

Where:

M: The maximum bending moment occurred in the beam loading location.

P = 59.2 tons = 59,200 kg.l14, 15]

L = 12.5 m.

W = 293.8 kg/m = 2.94 kg/cm. [14, 15]

The maximum center bending stress of the steel supporting beams is calculated by adopting the following equation (a):

$\boldsymbol{\sigma_{max} = M*y / Ix}$ …………………..…………. (b)

Where:

σ_{max}: The maximum stress occurred in the member edge of the beam loading location.

M: The maximum bending moment occurred in the beam loading location.

y: Distance between Neutral axis and member edge, it is 45.6 cm for H912*302*18*37 (refer to Figure 12)

Ix: the moment of inertia, it is 516,281 cm^4 for H912*302*18*37 (refer to Figure 12)

By adopting equations (a) and (b), the maximum σ and M is calculated as follows:

$\mathbf{M_{max}}$ **= 17,036,992 kg-cm**

$\boldsymbol{\sigma_{max}}$ **= 1,505 kg/cm²**

The maximum stress of the member edge is 1,505 kg/cm^2, which is less than the allowable stress of 1,512 kg/cm^2 of ASTM A36 carbon steel, represents a safe result of the H912*302*18*37 supporting beam on the bending stress caused by the superstructure loads.

For adequate control of the girder camber value, the deflection of the is also calculated by adopting the equation (c):

$\boldsymbol{\Delta_{max} = P*L^3/(48*E*Ix) + 5*W*L^4/(384*E*Ix)}$..(c)

Where:

Δ_{max}: The maximum deflection occurred in the beam loading location.

P = 59.2 tons = 59,200 kg.l14, 15]

L = 12.5 m.

W = 293.8 kg/m = 2.94 kg/cm. [14, 15]

E = Young's modulus, it is $2.1*10^6$ kg/cm2 for ASTM A36 steel material.

Ix: the moment of inertia, it is 516,281 cm^4 for H912*302*18*37 (refer to Figure 12)

After the calculation by using the equation (c), it is obtained the results ofΔ_{max} as follows:

$\mathbf{\Delta_{max}}$ **= 1.609 cm**

In this study, the electrical level equipment is used to verify the actual deflection of the supporting beams after the concrete placement of the U7 box girder. The surveying result for the Δ_{actual} is as follows:

$\mathbf{\Delta_{actual}}$ **= 1.59 cm**

To compare the actual deflection to the calculated results, the shoring system composed of the H912*302*18*37 supporting beams and steel truss frame had achieved outstanding performance and work for the construction of U7 box girder.

VI. CONCLUSION

In the Ankeng Light Rail MRT system (ALRMS) project, the U7 box girder passes crossing the Erbads creek and needs a temporary supporting system for the construction work. The D-B Contractor, New Asia construction and Development Corporation, evaluated and selected the optimal option, **The Steel truss frame with supporting beams**, to serve as the temporary supporting system. Compare the deflection of $\mathbf{\Delta_{max}}$ and $\mathbf{\Delta_{actual}}$, which are **1.609 cm** and **1.59 cm**, respectively. This result presented that the shoring system composed of the H912*302*18*37 supporting beams and steel truss frame had achieved outstanding performance and work to construct the U7 box girder. Not only the U7 box girder had been successfully and safely constructed, but also the Ecological and environmental issues are also been protected in this study. The authors conclude the **Steel truss frame with supporting beams** had performed a **sustainable solution for the Shoring Method of Cross-**

e-ISSN: 2250-0758 | p-ISSN: 2394-6962
Volume-11, Issue-1 (February 2021)
https://doi.org/10.31033/ijemr.11.1.3

Creek Bridge in Ankeng MRT system in New Taipei City.

REFERENCES

[1] Liu, T.Y., Chen, P.H., & Chou, N.N.S. (2019). Comparison of assessment systems for green building and green civil infrastructure. *Sustainability, 11*, 2117. Available at: https://doi.org/10.3390/su11072117.
[2] World Bank. (1994). *World development report 1994: Infrastructure for development*. Oxford, UK: Oxford University Press, pp. 1–12.
[3] World Bank. (2006). *Infrastructure at the crossroads: Lessons from 20 years of World Bank experience*. Washington, D.C., 1–9, 65–80.
[4] Shen, L., Wu, Y., & Zhang, X. (2011). Key assessment indicators for the sustainability of infrastructure projects. *Journal of Construction Engineering and Management*, *137*(6), 441-451.
[5] Geldermans, B., Tenpierik, M., & Luscuere, P. (2018). Circular and flexible infill concepts: Integration of the residential user perspective. *Sustainability*, *11*, 261.
[6] Sustainability Development Goals. (2020). *17 Goals to transform our worl*d. Available at: https://www.un.org/sustainabledevelopment/sustainable-development-goals/.
[7] Wikipedia. (2019). *Effects of global warming.* Available at: https://en.wikipedia.org/wiki/Effects_of_global_warming..
[8] Saha, D. (2018 Apr.). *Low-carbon infrastructure: An essential solution to climate change?*. World Bank Blog.
[9] Liu, T.Y. (2020). *Establishment of sustainability key indicators for civil engineering and their applications in green infrastructure projects*. Department of Civil Engineering, College of Engineering, National Taiwan University, Doctoral Dissertation. DOI: 10.6342-NTU202000235.
[10] Liu, T.Y., Chen, P.H., Chou, N.S., Chou, M.Y., Lin, R. J.C., Luo, & Han-Ding. (2019 Sep.). Environmental sustainability approaches adopted for construction of anhsin bridge of ankeng metro system in New Taipei city. *E3S Web of Conferences, 117*, pp. 00013.
[11] Liu T.Y., Lee, C.A., Chou, M.Y., Chang, P.H., Lin J.J., & Lan, W.C. (2020). Sustainability approaches adopted for storm water and deposit ponds construction of ankeng mrt system in new Taipei city. *Global Journal of Engineering Science and Research Management*. DOI: 10.5281/zenodo.4059507.
[12] Asia Construction and Development Corp. (2017). *Working plan for Casi-in-Place Bridges for the Ankeng Light Rail Metro System construction project*. Taiwan, R.O.C., (2017, in Chinese)
[13] New Asia Construction and Development Corp. (2017). *Temporary shoring system arrangement planfor the Ankeng Light Rail Metro System construction project*. Taiwan, R.O.C., (2017, in Chinese)
[14] New Asia Construction and Development Corp. (2016). *Calculation sheet for temporary shoring system for the Ankeng light rail metro system construction project.* Taiwan, R.O.C., (2016, in Chinese)
[15] New Asia Construction and Development Corp. (2016). Calculation sheet for U7 box girder supporting beams for the Ankeng light rail metro system construction project. Taiwan, R.O.C., (2016, in Chinese)