IOP Conference Series: Materials
Science and Engineering

A comprehensive review of incremental launching method in the construction of prestressed reinforced concrete bridges in Vietnam

To cite this article: Viet Duc Dang and Gia Nai Dang 2023 *IOP Conf. Ser.: Mater. Sci. Eng.* **1289** 012013

A comprehensive review of incremental launching method in the construction of prestressed reinforced concrete bridges in Vietnam

Viet Duc Dang[1], Gia Nai Dang[2,*]
[1]Thuyloi University, Hanoi, Vietnam

[2]Vietnam Bridge and Road Association, Hanoi, Vietnam

[*] Corresponding author's e-mail: danggianai47@yahoo.com

Abstract. This paper discusses the implementation of the incremental launching method in the construction of prestressed reinforced concrete bridges in Vietnam. Since the 1990s, technology transfer has been initiated to develop and rapidly expand the country's road and rail transport network system to support industrialization and modernization. Although the method was successfully applied in several bridge projects, the high construction cost has led to a controversial issue, and the government stopped its application in the country. The paper aims to analyze the limitations and unreasonableness in the project formulation, design survey, and procurement of technological equipment that led to the policy of stopping the application of the incremental launching method. The author provides an in-depth analysis to clarify the suitability of the policy and shed light on the issue's root causes.

1. Introduction
The construction of prestressed reinforced concrete bridges with large spans has been a priority for Vietnam's transport sector since the early 1990s [1]. To achieve this goal, the industry has implemented several projects using advanced technology transfers. One of these technologies is the incremental launching method, which has been applied in the construction of several prestressed reinforced concrete bridges. Incremental launching serves as a unique construction technique employed for bridge building, aimed at tackling accessibility challenges or minimizing disturbances at ground level. Specifically, incrementally launched prestressed concrete bridges are constructed in segments within a designated casting bed. Once completed, these segments are gradually pushed out of the casting bed, creating room for the construction of subsequent segments. The successful design of an incremental launch bridge necessitates specialized expertise and meticulous coordination of temporary works. The majority of superstructure construction activities take place within the casting bed vicinity, enabling the installation of bridge barriers, lighting fixtures, and drainage systems before the launching process [2].

The successful application of the incremental launching method in the construction of Hien Luong bridge (NH1A-Quang Tri) led to the use of this technology in other projects, including Quan Hau bridge (NH1A-Quang Binh), Ha Nha bridge (NH14B), Sao Phong bridge (NH12A-Quang Binh), Dinh bridge (Nghe An), and Met bridge (NH1A-Lang Son), among others. However, the high cost of this method compared to other types of simply supported girder bridge construction technologies has caused controversy, and its economic efficiency has been called into question. In some cases, the cost has been reported to be 1.5 times more expensive, and in extreme cases, nearly double the cost of other methods like the Mat bridge [1, 3, 4].

As a result, the government stopped using this technology in bridge construction, while many other countries have continued to apply it widely [5-9]. To clarify the issue, this paper presents an in-depth analysis of the limitations and unreasonableness in the process of project formulation, design survey, and procurement of technological equipment. The goal of this analysis is to determine the suitability of the policy of stopping the application of the incremental launching method in Vietnam. This paper also provides valuable insights into the economic efficiency and applicability of the incremental launching method in the construction of prestressed reinforced concrete bridges in Vietnam. The findings of this research could have important implications for the country's transport sector, as it strives to improve the efficiency and cost-effectiveness of infrastructure development projects.

2. Analyzing limitations of the method in terms of construction cost

2.1. Increased costs from not fully grasping the technology

The Hien Luong Bridge was selected by the Vietnamese investor agency to serve as a test project for the incremental launching method, which was fully transferred from the Russian Federation. Given that this was a new technology being tested, the cost factor was not a primary consideration. However, due to the bridge's short length, which is not suitable for the application of this method, it cannot be considered as an alternative for reducing costs through the use of this new technology.

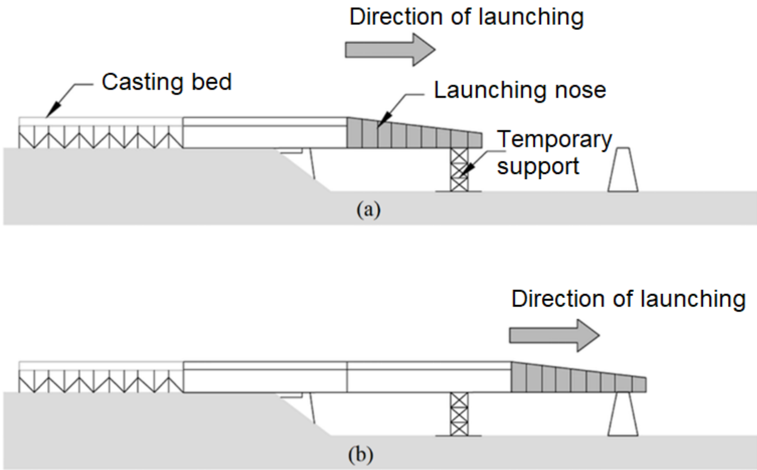

Figure 1. Incremental launching method: (a) Step 1, (b) Step 2 [5].

The bridge's length of approximately 231 meters is too short to achieve economic efficiency through the incremental launching method. Experience from countries that have applied this method for many years indicates that a casting bed must be built on the approaching road to the bridge, located directly behind the abutment (Figure 1). After the completion of the girder pushing work, all the casting bed components will be filled with soil from the bridge approach. As a result, a significant amount of concrete and steel from the foundation will be lost without being reused, particularly for short bridges where the proportion of material loss will be greater than for longer bridges. The incremental launching method is only effective when the bridge's length is large enough, typically between 250-1000 meters, as indicated by the experiences of other countries [6-9]. Figure 2 depicts the economic efficiency of the two solutions of the incremental launching method and the construction technology on the fixed scaffolding system applied in the construction of two equivalent prestressed reinforced concrete viaducts.

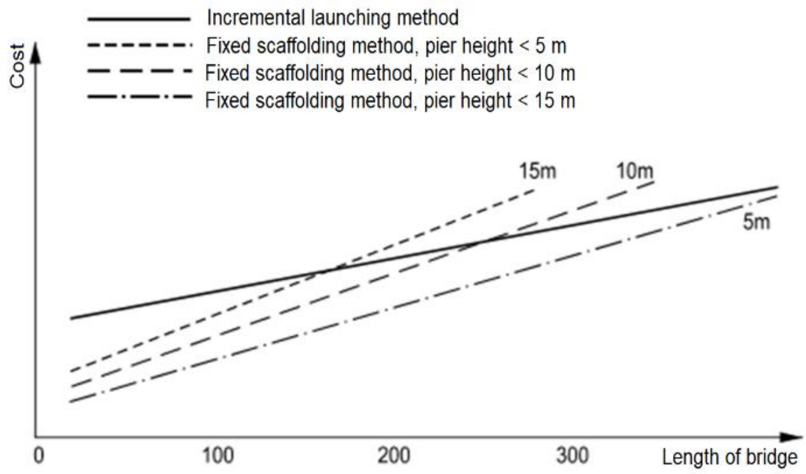

Figure 2. Comparing the economic efficiency of two methods: The incremental launching method and the construction technology on the scaffolding system.

In Figure 2, a comparison between the technology of pouring concrete on a fixed scaffolding system and the incremental launching method can be made. For viaducts, when the pier height is less than 5 m, the incremental launching method is more cost-effective for bridge lengths greater than 500 m, but for bridges shorter than 500 m, it is more expensive. However, for bridges with pier heights greater than 10 m, the incremental launching method becomes more economically efficient for bridge lengths greater than 270 m [3]. In addition, in the case of pier heights greater than 15 m, this method is greatly efficient for bridge lengths more than 170 m.

Unfortunately, Hien Luong bridge's location over a river makes it difficult to use the fixed scaffolding system technology. Additionally, the short length of the bridge is another factor that increases the cost due to the loss of material from the casting bed. Moreover, the short length of the bridge reduces the efficiency of the system of equipment, machinery, and human resources, as the equipment and skilled technicians can be more efficiently utilized for bridges with longer lengths due to the same type of installation. Furthermore, the construction work at each translation will contribute to rationalizing production in the direction of industrialization, modernization, and economic efficiency, ultimately improving cost efficiency.

As a result, the Hien Luong bridge, along with other bridges built using the incremental launching method of the Russian Federation with a length of less than 231 m, will have low economic efficiency due to their high cost.

2.2. Increased cost from consulting work

There are still limitations in the implementation stages of consulting on project formulation, design survey, and procurement of technological equipment. The most apparent limitation is the continued use of the incremental launching method (as designed by the Russian Federation) for a series of bridge constructions, including the Hien Luong bridge, despite their shorter length (200-230 m) not be suitable for this method. This issue is even more unreasonable in the case of the Met bridge, which has a length of only 90 m. With a span of only 3 simply supported bridges, applying traditional construction methods would have been straightforward and significantly reduced the cost of the project. However, the design project was instead reconfigured to use the incremental launching method, resulting in a doubled cost (almost twice the original estimate using simple beams). This irrationality, as shown in Figure 2, has increased the cost of the project and prevented it from fully realizing the benefits of this method.

2.3. Increased cost from restrictions in purchasing equipment

2.3.1. Hien Luong bridge. From 1994 to 1997, the Russian side carried out technology transfer for the Hien Luong bridge project. Unfortunately, the equipment brought back from Russia was outdated and no longer widely applied at that time. Figure 3 depicts the solution of pushing the girder on one point using an anchorage system. The jacking system, consisting of four jacks, each with a capacity of 240 tons, is placed on the transverse girder through the belly, and the beam has already been cast on the bed. An anchorage system is built in front of the abutment to transmit the supporting force, which is mainly subjected to lateral forces transmitted by the drawbar. However, this system has generated additional construction work due to its position in front of the abutment, making pile driving work on the river more complicated and increasing construction costs. Alternatively, moving the abutment back to the riverbank would increase the length of the bridge. Moreover, the horizontal jacking capacity of the push-pull equipment brought back from Russia was limited to <960 T (4x240 T/jack), constraining the length of the bridge constructed by the incremental launching method to < 500 m [10-12].

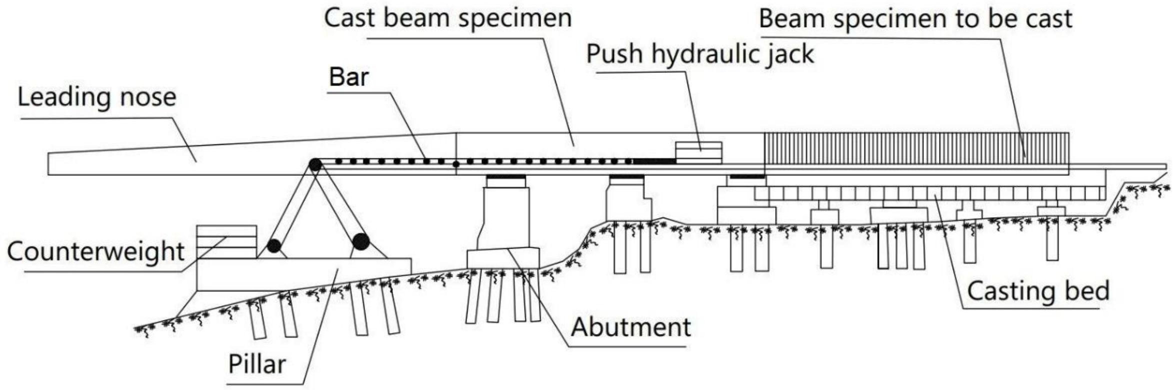

Figure 3. Anchorage system for the pulling method.

2.3.2. Limitations in technology transfer of the Met bridge. Unlike the synchronous transfer approach employed at the Hien Luong bridge, the partial transfer method was implemented for the Met bridge project. Under this method, the Vietnamese side was responsible for project planning and design surveys, while OVM (China) provided the entire technological operational equipment. In addition to the limitations in consulting work discussed in Section 2.2, several technical problems were observed in the project, particularly with the set of formworks used for casting beams. The height of the girder was approximately 2.65 m, which was equal to the formwork set height. However, the maximum span length was only 40 m. In comparison, the girder of the Hien Luong bridge had a span length of 42 m and a height of 2.5 m, while the simple girder spans super T 40m had a height of only 2.0 m. The cross-sectional design parameters were overly conservative, resulting in an excessive volume of concrete and steel materials and high construction costs [10, 13].

A detailed study of the operating mechanism of the Met bridge push-casting system also revealed several issues. Due to the length of the formworks at 9.0 m (2x4.5 m), the casting length of the beam was limited to only 9 m. This short firing length resulted in each push-molding cycle (14 days) being capable of pushing only 9 m of the bridge length. In contrast, the Hien Luong bridge had a casting length of 21 m, enabling each cycle to push the folded bridge over more than twice the length compared to the Met bridge. This limitation significantly prolonged the project's construction time, leading to an increase in the project's cost and price.

3. Proposed technical solutions

3.1. Using multi-point pushing or lifting-pushing method

As discussed above, the one-point pushing method shows its ineffectiveness, which requires the anchorage system and the hydraulic jack with very high capacity. To solve this problem, the solution to push on many points is an alternative. Figure 4 shows the push principle of the multi-point pushing solution, which involves dividing the horizontal thrust into multiple jacking points positioned on the pillars. For instance, jacking points are arranged at the support points of the abutment and pier. With an increase in the beam weight when pushing (i.e., an increase in beam length), jacks are added to match the beam weight. The primary advantage of this method is that it can actively increase the thrust, allowing for the construction of longer bridges compared to the method of pushing on a fixed push point, which limits the length of the bridge.

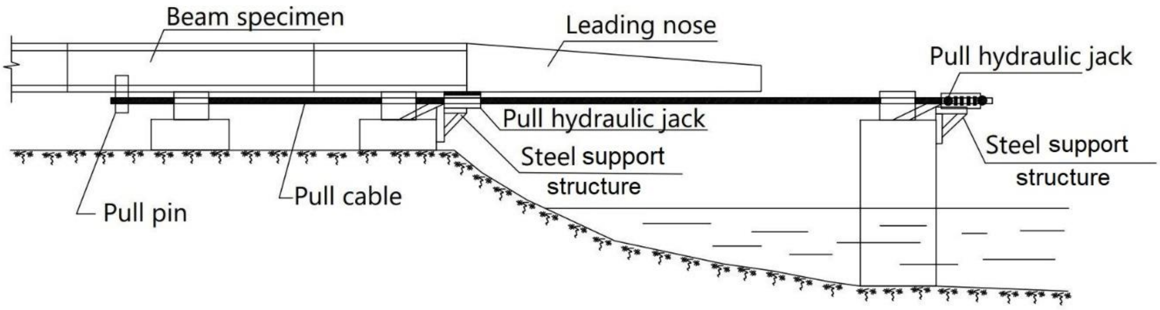

Figure 4. Pushing beams over multiple points.

A more advanced technique is the lifting-pushing method, which is a multi-point pushing technology solution that requires a horizontal and vertical jacking system to raise the beam. The horizontal jack directly applies thrust to the vertical jack. The vertical jack is placed on the sliding system (as shown in Figure 5) with the jack head placed on the bottom of the girder to bear the weight of the beam itself. When subjected to force from the horizontal jack, the entire jack simultaneously lifts the beam and moves the slide forward.

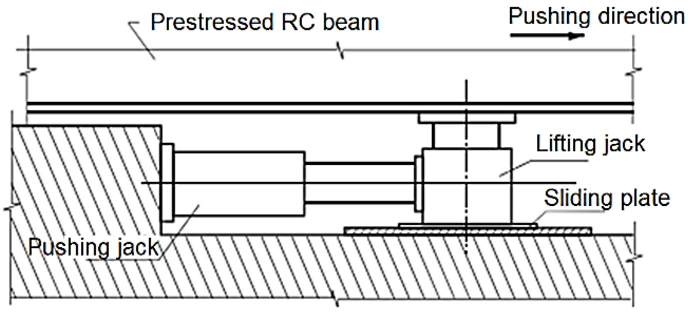

Figure 5. Lifting and pushing on multiple points.

The lifting method is an effective solution for pushing heavy beams without causing a strong impact on the abutment, which is often caused by the weight of a large horizontal force. This technology allows the horizontal thrust to be divided into many jacking points, providing the advantage of actively increasing the thrust and enabling the construction of longer bridges without limitations. The use of a vertical jack on the sliding system allows for the simultaneous lifting of the beam and forward movement, reducing construction time and costs.

3.2. Regarding the unreasonable layout of prestressing cables of conventional beams

In the traditional prestressed girders, the prestressing cable strand bundle diagram is mainly designed to subject the negative and positive moments during the construction phase (Figure 6(a)), but this diagram is also used for the service phase. Therefore, there have appeared in unfavorable load-bearing positions.

Due to the priority of load bearing in the construction phase, during the service phase, counterproductive factors about bearing forces at unfavorable load-bearing positions arise. Observing Figure 6(a) shows that spans 1, 2, 3, and 4, only contain the strand bundles "D" that are subjected to the positive moment, while the strand bundles "T" cause top compressive stress and bottom tensile stress, leading to a reduction of bending resistance of the girder. This is also observed in piers I, II, and III, the strand bundle "T" is subjected to negative moment, while the strand bundles "D" are useless.

However, for the construction using fixed or movable scaffolding systems that allow designing strand bundles to be suitable with internal force diagrams; therefore, there is no phenomenon of cable bundles working backfire, which increases economic efficiency. Some figures illustrating this are shown in Table 1.

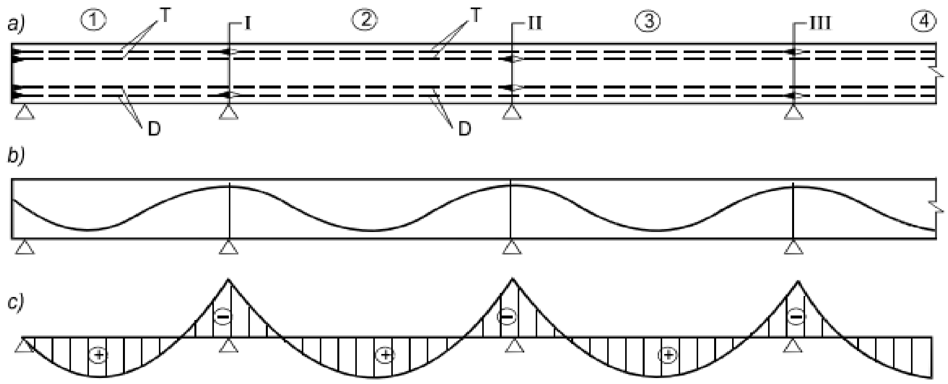

Figure 6. (a) Solution for arranging bundles from the traditional point of view, (b) Characteristic cable bundle curve of continuous girders, (c) Diagram of internal force distribution (moment) of a continuous beam.

Table 1. Comparison of material usage criteria.

Technologies	Concrete (T/m^2)			Reinforcement (T/m^2)		
	L = 42 m	L = 45 m	L = 50 m	L = 42 m	L = 45 m	L = 50 m
Incremental launching method	1.116	1.134	1.149	0.017	0.017	0.0204
Fixed and moveable scaffolding systems	1.078	1.097	1.125	0.013	0.013	0.0127

3.3. Improvement of prestressed cable bundle layout diagram of conventional girders

The enhanced design of cable bundles prioritizes the service phase but must also meet the requirements of bearing force changes during the beam-pushing construction phase. To satisfy this demand, curved bundles (similar to the curved form of beams constructed on fixed or movable scaffolding systems) will be installed under tension during the beam-pushing process (Figure 7). To accommodate the change in load bearing, temporary straight cable bundles (Figure 7) with additional tension will be utilized at locations where the bent bundle is not yet capable of bearing the force (bending moment) during the construction phase to push the beams. These temporary cable bundles can be easily removed and repositioned during beam pushing. Once the push-up work is complete, the cable bundles are temporarily removed. To prevent the reaction phenomenon during the beam-pushing phase, the number of curved cable bundles only meets a portion of the service load, so after the push, the beam will stretch the cable bundles at unfavorable bearing locations (on piers and between spans). Figure 8 illustrates the arrangement of the curved and regular cable bundles [10, 14].

By enhancing the cable bundle layout scheme to conform to the internal force curve law, the impractical structure limitations of traditional reinforced concrete beams and the improved beams have been overcome.

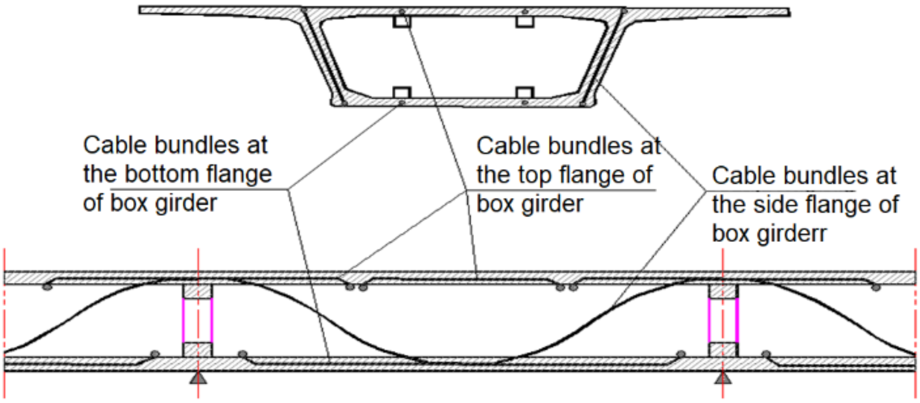

Figure 7. Layout diagram of curved and straight cable bundles in the construction phase.

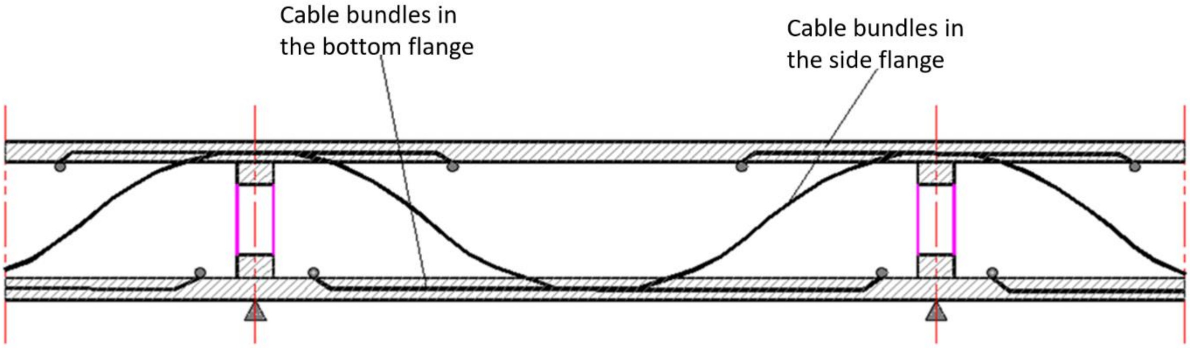

Figure 8. Cable bundle layout diagram in the service phase.

4. Conclusions

In conclusion, the incremental launching method has demonstrated efficiency and effectiveness in constructing medium-span prestressed reinforced concrete bridges. This construction technique has gained widespread adoption in numerous countries due to its advantageous features, including its ability to adhere to strict construction schedules and its suitability for large-scale projects, especially for overhead bridges and overpasses at intersections with varying levels. Therefore, it is highly recommended to explore the extensive application of this method in the construction of prestressed reinforced concrete bridges in Vietnam.

To ensure the continued application of this method, it is necessary to study and adjust the traditional prestressed cable layout to prevent counterproductive forces during the exploitation phase, thus optimizing material use. Additionally, a comprehensive review of the application of this method in Vietnam during the period from 1995 to 2000 should be conducted to draw correct conclusions about its advantages and disadvantages, as well as the causes of increasing costs in some bridge projects. This review will enable a re-evaluation of the policy of stopping the application of this method since 2000.

In summary, the incremental launching method offers great potential for the construction of prestressed reinforced concrete bridges in Vietnam. With proper adjustments and a comprehensive review of past applications, this method can be effectively implemented to contribute to the development of Vietnam's transportation infrastructure.

References

[1] Dang GN 2000 On incremental launching technology in bridge construction for Vietnam Second *Asia Pacific Conference & Exhibition on Transportation and The Environment* 11-13 April 2000 Beijing, China
[2] Midas 2021 Structural Analysis of Incrementally Launched Bridge / Available: https://wwwmidasbridgecom/en/blog/casestudy/structural-analysis-of-incrementally-launched-bridge
[3] Dang GN 2008 Research and analyze the economic and technical efficiency of the application of new structures and technologies in the construction of prestressed reinforced concrete bridges and propose directions *Vietnam Road and Bridge Magazine*
[4] Nguyen MG 2001 Application of incremental launching method in bridge constructions in Vietnam *Master Thesis* (in Vietnamese)
[5] Tomasz Siwowski 2015 *Bridge Engineering Selected Issues* Oficyna Wydawnicza Politechniki Rzeszowskiej (al Powstańców Warszawy 12, 35-959 Rzeszów)
[6] Reinbeck U 1985 The incremental launching method in bridge construction *Transactions of the Institution of Professional Engineers* New Zealand: Civil Engineering Section **12**(2) 57-64
[7] Fontan AN, Hernández S, and Baldomir A 2014 Simultaneous cross section and launching nose optimization of incrementally launched bridges *Journal of Bridge Engineering* **19**(3) 04013002
[8] Rosignoli M 1997 Influences of the incremental launching construction method on the sizing of prestressed concrete bridge decks *Proceedings of the Institution of Civil Engineers-Structures and Buildings* **122**(3) 316-325
[9] Tung HS, Pang MT, Roblin EJ, Tang MC, Shawwaf K, Conway TP, and Mak YM 1988 The first incrementally launched bridges in Hong Kong *Canadian Journal of Civil Engineering* **15**(1) 24-36
[10] Dang GN 2009 Prestressed reinforced concrete bridge construction with incremental launching method *Construction Publishing House* (in Vietnamese)
[11] Dang GN 2001 The application of incremental launching method for the construction of Met Bridge and Hien Luong Bridge *Vietnam Road and Bridge Magazine* (in Vietnamese)
[12] The technical design of Hien Luong bridge 1994 Moscow (in Russian)
[13] The technical design of Met bridge 1994 TEDI (in Vietnamese)
[14] KC10-09 project (1991-1993) Application of advanced technology in the construction of large-span prestressed reinforced concrete bridges (in Vietnamese)