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Original Research Article

Theoretical geometry of Karbandi expansion and development: A case study of sixteen-sided Karbandi

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Abstract

The expansion of Karbandi is one of the methods of creating various covers in traditional architecture, and the expanded Karbandi has an important role in historical architecture of Iran. However, this type of Karbandi has not been properly considered in the existing typologies, and few, if any, targeted pieces of research have already been performed on how Karbandi is developed and expanded. All that is provided is inadequate attempts within other works. To provide a better understanding of the traditional structures, this research has investigated the theoretical geometry of Karbandi development and expansion, the development of the base to achieve more diversity and the requirements of Karbandi implementation on new bases. The research has adopted a descriptive-analytic approach and logical reasoning to examine geometric propositions. The data collection was done through library research and computer modeling, and a sixteen-sided Karbandi was selected as the study sample to verify the research results. The results showed that an expanded Karbandi is a compound type of Karbandi produced by the intersection of two or more identical or non-identical mother bases to provide various forms according to the type of those two components and the connection distance. The expanded Karbandi base can be shaped by three methods including peripheral geometry, non-elimination geometry and elimination geometry. Therefore, this type of Karbandi can be implemented on all the bases of regular polygons, irregular polygons with axial symmetry, and irregular polygons without axial symmetry in its specific conditions. In peripheral geometries, the connection distance conditions are similar to those of Karbandi on a mother base; however, in elimination and non-elimination geometries, the number of dividing points between two adjacent bases with the greatest distance from each other determines the minimum connection distance in them. On the bases with non-elimination geometry, due to the increase in the number of columns and, hence, the decrease in the distance between adjacent columns, the connection distance limit is reduced compared to that in a simple Karbandi. Therefore, this type of Karbandi can be implemented in more situations.

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Extended Abstract

1. Introduction

Due to its chord geometry, Karbandi has more variety and flexibility in covering different areas than other traditional coverings such as domes and arches. This structure has attracted the attention of many researchers, and much research has, thus, been done on Karbandi's geometry and typology. Nevertheless, there has been no targeted research on how Karbandi is developed and expanded, and all that has been observed with this theme is a few citations within studies. With the aim of providing a deeper understanding of traditional architectural structures, the current research has investigated the theoretical geometry of expansion and deployment of Karbandi (apart from execution issues) and focused on the development of bases to achieve more diversity. The research aims to answer the following questions:

- What is the position of expanded Karbandi in typology and how is it formed geometrically?
- How can the base shape be developed and more diverse bases be create by expanding Karbandi?
- On the expansion Karbandi bases, what are the conditions for implementing Karbandi's geometry?

2. Research Methodology

The research has adopted a descriptive-analytic approach and logical reasoning to examine geometric propositions. The data collection was done through library research and computer modeling, and sixteen-sided Karbandi was selected as the study sample to verify the research results. In this research, first, Karbandi geometry and its formation were investigated using library resources and documents. Then, based on the definitions of expanded Karbandi in the literature, Karbandi expansion and development method is discussed. To verify the results, different expansion states of sixteen-sided Karbandi were investigated by computer modeling.

3. Results and discussion

In expanded Karbandi, as in simple Karbandi, the two factors of base shape and connection distance are effective in creating diverse forms. The base shape in this type of Karbandi is obtained from the geometric modes that are possible for intersecting two mother bases; therefore, multiple bases are achieved for each intersection with regard to the intersection angle, the similarity or dissimilarity of bases, and the geometric modes used in base drawing (i. peripheral geometry, elimination geometry and non-elimination geometry). Geometrically, in an expanded Karbandi, the intersection of two mother bases can create more coverage, compared to a simple karbandi. According to the base drawing geometry, comparison has been made between the connection distances of expanded Karbandi and simple Karbandi in three situations. On the bases that are formed by drawing peripheral geometry, the coverage area is limited to mother bases. Therefore, the distance requirements will be similar to those in a simple Karbandi. If the connection distance is greater than or equal to the number of distances against the base length, Karbandi can be implemented. In this situation, if the two intersecting bases are dissimilar, the base with the greater

length will be the criterion for determining the minimum connection distance. On bases with non-eliminating geometry, the base coverage level has increased and the connection distance limit has decreased, compared to the simple Karbandi. In this Karbandi, the maximum distance between adjacent columns determines the minimum distance between the connection points. Due to the increased number of columns in the expanded Karbandi, it has a smaller size than a simple Karbandi and can, thus, be implemented in a larger span. Therefore, in some spans that are not formed on the mother base of Karbandi, a non-removable expanded Karbandi can be drawn. In elimination bases, the neighboring columns with the longest distance from each other will be the criterion to determine the minimum connection distance. However, since part of the mother base is removed in this type of bases, it is not possible to express a definite comparative opinion about the connection distance with a simple Karbandi, and each sample should be checked on a case-by-case basis. In general, it can be said that, in these bases, due to the removal of some columns and the increased distance between columns, the distance limit is increased, compared to non-elimination geometries.

4. Conclusion

A literature review showed that Karbandi structures are variously named and that adequate attention has not been paid to Karbandi typology. This study provides a typology of Karbandis based on their formation geometry, discussing the theoretical geometry of their expansion. The results showed that expanded Karbandi includes numerous Karbandis on regular, symmetric irregular, and asymmetric irregular with specific geometry bases and that its frequency of forms on a particular base can be much more than what is found in traditional architecture. Many Karbandis in traditional architecture are in this category. Todays, by the increased use of software in designing problems and the diversity of materials in covering applications, it is possible to derive various forms from Karbandi geometry. Therefore, recognizing the geometry of expansion and development of Karbandi can prepare the ground for the creation of new forms in the discussion of updating Karbandi.

Two main problems in the discussion of expanding Karbandi are the way the geometry of the base is formed and the requirements of the connection distance on the new base. The final shape of the base is caused by the intersection of the bases, their being identical or non-identical, and the drawing methods used (peripheral, non-eliminative and eliminative geometries). This is how various shapes of bases are attainable. Besides, a base with non-eliminating geometry is more abundant in traditional architecture. All kinds of irregular and asymmetric shapes can be formed through elimination geometry, which is less regarded and practically less implemented in traditional architecture. The connection distances in an expanded Karbandi are determined by the base geometry. On the bases with non-eliminative geometry, due to the significant expansion of the coverage level of Karbandi and the increase in the number of bases and, hence, in the distance between the neighboring bases, the connection distance limit is decreased, compared to simple Karbandi. Therefore, the Karbandi can be implemented in more cases. In peripheral geometry, the connection distance limit is similar to that in the mother base.

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