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# Numerical evaluation of expansion loops for pipe subjected to thermal displacements

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## Abstract

The thermal expansion can lead to the high stress on the pipe. The problem can be overcome using expansion loops in a certain length depending on the material's elastic modulus, diameter, the amount of expansion, and the pipe's allowable stresses. Currently, there is no exact definition for the dimension of expansion loops design both for loop width (W) and loop footing height (H) sizes. In this study, expansion loops were investigated with using ratio of width and height (W/H) variations to understand pipe stress occurring on the expansion loops and the expansion loops' safety factor. Relationship between non dimensional stress on the expansion loop pipe was studied numerically by finite element software on several working temperatures of 400oF, 500oF, 600oF, and 700oF. It can be found that stress occurring on the pipes increases as the increases of W/H of the expansion loops and results in a

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# Numerical evaluation of expansion loops for pipe subjected to thermal displacements

*Hartono Yudo, Sarjito Jokosisworo, Wilma Amiruddin, Pujianto Pujianto, Tuswan Tuswan, Mohamad Djaeni*

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Research Article

Hartono Yudo*, Sarjito Jokosisworo, Wilma Amiruddin, Pujianto Pujianto, Tuswan Tuswan, and Mohamad Djaeni

# Numerical evaluation of expansion loops for pipe subjected to thermal displacements

https://doi.org/10.1515/cls-2022-0007
Received Jun 27, 2021; accepted Oct 08, 2021

**Abstract:** The thermal expansion can lead to the high stress on the pipe. The problem can be overcome using expansion loops in a certain length depending on the material's elastic modulus, diameter, the amount of expansion, and the pipe's allowable stresses. Currently, there is no exact definition for the dimension of expansion loops design both for loop width ($W$) and loop footing height ($H$) sizes. In this study, expansion loops were investigated with using ratio of width and height ($W/H$) variations to understand pipe stress occurring on the expansion loops and the expansion loops' safety factor. Relationship between non dimensional stress on the expansion loop pipe was studied numerically by finite element software on several working temperatures of 400°F, 500°F, 600°F, and 700°F. It can be found that stress occurring on the pipes increases as the increases of $W/H$ of the expansion loops and results in a lower safety factor. The safety factor of the expansion loops pipe has a value of 1 when the ratio of loop width and loop footing height ($W/H$) value was 1.2 for a 16-inch diameter pipe. Stress occurring on the pipe increases with the increase of the working temperature. Expansion loops pipe designed for 400°F can still work well to handle thermal extension pipe occurring on 500°F.

**Keywords:** Thermal expansion, expansion loop, safety factor

## 1 Introduction

Thermal expansion on a pipe is one of the problems in designing a piping system because it can lead to high stress on a pipe. This case can cause fatal damage to the system. Therefore, the study and design are necessary to avoid damaged piping systems due to the thermal expansion [1]. One of the methods used to prevent damage to the piping system is by using expansion loops that can be used to increase designed piping system flexibility [2]. Huang *et al.* [3] have confirmed that flexible branch heat pipe has a larger maximum heat load than the straight pipe. Meanwhile, the other study showed that a flexible pipe with a repeated unit cell had a strong correlation between the repeated unit cell model and the analytical models with some difference in the wire bending stresses [4]. This research also found that the repeated unit cell model is robust and computationally efficient for analyzing flexible pipes [4]. Tang *et al.* [5] have analyzed that an increase in the winding angle of the tensile armor wires and damage to the outer sheath of the flexible pipe decreased the compressive stiffness significantly. Yoo *et al.* [6] have analyzed flexible pipes which aims to improve the convergence of nonlinear analysis by simplifying interactions between layers. The result showed the model was subjected to incremental axial tension, and the overall stiffness decreases due to the progressive failure of tensile armour layers. The inner tensile armour yields first, and the outer tensile armour layer follows. Moreover, Hastie *et al.* [7] have confirmed that increasing the internal temperature causes a drastic rise in the inner liner failure coefficient of pipe under low pressure. Thermal expansion occurring on the pipe depends on the expansion coefficient of the pipe material during working temperature and pipe length. Value of expansion coefficient during work temperature can be found on American Society of Mechanical Engineers (ASME) B3 1.1 about Power Piping ASME Code for Pressure Piping [8]. Jaćimović [9] believes that there might be an issue with the code philosophy concerning the thermal expansion stress range. An overstressed piping element may be deemed acceptable. Total occurring expansion on the pipe over working temperature is based on the design of

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Research Article

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# Application of generalized equations of finite difference method to computation of bent isotropic stretched and/or compressed plates of variable stiffness under elastic foundation

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**Abstract:** The computation of bent isotropic plates, stretched and/or compressed, is a topic widely explored in the literature from both experimental and numerical point of view. We expose in this work an application of the generalized equations of Finite difference method to that topic. The strength of the proposed method is the ability to reconstruct the approximate solution with respect of eventual discontinuities involved in the investigated function as well as its first and second derivatives, including the right-hand side of the equilibrium equation. It is worth mentioning that by opposition to finite element methods our method needs neither fictitious points nor a special condensation of grid. Well-known benchmarks are used in this work to illustrate the efficiency of our numerical and the high accuracy of calculation as well. A comparison of our results with those available in the literature also shows good agreement.

**Keywords:** rectangular plate, elastic foundation, generalized equations of finite difference method, discontinuity

## 1 Introduction

One can start by recalling that a plate is a structure, which thickness is small beside its length and width. What happens when you crumple up a sheet of paper? How does a general raft supporting a building behavior? Can the futuristic roofs that adorn our most glorious buildings (shopping centers, airport buildings…), resist the wind? In which way the carrosseries of a car is distorted in an accident? Here are some of many scenarios of structure behavior that arise in real life problems. Characterizing the deformations undergone under certain constraints is our aim in this work. The issues related to this study are diverse: it will sometimes be a question for the engineer of designing resistant and / or aesthetic plates or shells. Sometimes covertly, the plate specifications must provide the deformations distributed

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Research Article

Ali Safaeianpour and Nima Valibeig*

# A study on the construction technology of the Seljuk minarets in Isfahan with focus on their geometric brick pattern

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**Abstract:** Using decorative elements is an inseparable aspect of Iranian architecture. Architectural ornaments in many buildings, including the minarets, represent the architect's craftsmanship. As such, the minarets in Isfahan have different types of brickwork ornamentations, such as 90-degree herringbone *(Khofteh-Rasteh)*, basket weave bond *(Hasiri)*, and other complex types. Additionally, the highest minarets are usually constructed in a truncated conical shape to reduce their overall weight and ameliorate their stability against the wind, and lateral forces. Therefore, while the geometric integrity of brickwork patterns should be maintained, all the ornamentations are applied on a shrinking surface area. However, the practical solutions for the construction processes in these structures haven't been sufficiently investigated. Hence, this study aims to explore the methods of brickwork projection on the minarets and analyse the changes in girih patterns at different height levels. Accordingly, after surveying the selected single minarets in Isfahan, they were modeled using drafting software applications and then analysed.

**Keywords:** minarets of Isfahan, use of brick tile (girih) on curved façade, geometry in architecture, brickwork, geometric pattern

## 1 Introduction

The minaret is an architectural type with symbolic significance in the Middle East. The exterior surface is usually ornamented with brickwork patterns that are designed through mathematical and geometric calculations. Because of the minaret's overall shape, the brick patterns are constructed on a greater surface area at the bottom compared to the available surface at the upper parts. In other words, the cross-section diameter is gradually decreased during the construction; consequently, the surface area will be reduced as well. As a result, in projecting these brickworks on a shrinking surface, retaining the geometric integrity of these patterns could become very challenging. Nevertheless, even though the cross-section diameter is decreasing, the overall design should cover the exterior façade completely. Similarly, in implementing these patterns on the minaret, the pattern should be put together around the surface accurately and appropriately; that is, an implemented design without overlapping parts at different height levels. Besides, the integrity of geometric order in the implemented patterns should be successfully maintained.

Therefore, this study aims to answer these questions:

- How a two-dimensional brickwork pattern on the minaret's three-dimensional curved surface could be implemented without losing the integrity of geometric order?
- What practical solutions have been developed to maintain the geometric integrity on the minaret's cone-shaped surface?

### 1.1 Research background

Most previous studies about girih patterns are concerned with two-dimensional planes. So, this study is one of the earliest endeavors in analysing and addressing the challenges regarding the implementation of these patterns in three-dimensional structures and the practical solutions thereof. In previous studies about the application of girih in brickwork and the architectural geometry, traditional craftspeople (such as Lorzadeh, Maher-ul-Naghsh, and Sha'rbaf) and architects (such as Pirniya and Bozorgmehri) have discussed the implementation of girih patterns thoroughly [1]. In other studies, girih patterns have been seen concerning connections to mathematics [2]. Moreover, the similarity of

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