Frontiers of Architectural Research (2017) 6, 89–95

Available online at www.sciencedirect.com

Frontiers of Architectural Research

www.elsevier.com/locate/foar

Higher Education Press

SOUTHEAST UNIVERSITY

RESEARCH ARTICLE

Considering functional dimensioning in architectural design

Jean-Joseph Savoini, Zoubeir Lafhaj*

Mechanic and Civil Engineering, Ecole Centrale de Lille, Villeneuve d'Ascq 59651, France

Received 8 September 2016; received in revised form 4 January 2017; accepted 5 January 2017

KEYWORDS
Tolerance;
Architecture;
Construction;
Dimensioning;
Quotation

Abstract
This paper presents an overview of the functional dimensioning (FD) concept applied to the construction sector. FD addresses the issue of tolerance; construction involves several trades working together while each trade has its own construction tolerances. To investigate this problem, three case studies are investigated. The first one describes a classic case of a window in a bay and the way constructors solved the resulting tolerance problems. The second case study describes the notion of chain dimension. The last case study presents the notion of wedge as a solution to solve problems related to tolerance gap accumulation. This paper is of interest to the scientific community that is working to industrialize the construction sector and also to architects (in the design), construction managers (onsite), and manufacturers (construction trades).

1. Introduction

Functional dimensioning (FD) is a dimensioning system designed to define the dimensions of an element so that its function (e.g., sliding of the piston in its support or a drawer) can be ensured regardless of the incoming part and the receiving one. Another definition by Ciurana et al. (2003) is the selection of the correct dimension and tolerance to optimize the parts according to the definition of the mechanical assembly for their functional purpose.

Until the end of the nineteenth century, production could be realized without a deep understanding of FD. Drawings were exploited without an advanced level of details unlike in today's industry (Campbell, 2004), especially with the advent of product flexibility and customization needs of the client (Khalili-Araghi and Kolarevic, 2016). The questions related to product fabrication tolerances were first investigated after the mass production of the Ford Model T; industrialization was launched hand in hand with product quality control. Now that precision is compulsory for different industries (nanoprecision), software is now used to solve complex geometrical tolerance problems (Islam, 2004; Khajehdehi and Panahshahi, 2016).

*Corresponding author.
E-mail addresses: zoubeir.lafhaj@ec-lille.fr, zoubir.lafhaj@gmail.com (Z. Lafhaj).
Peer review under responsibility of Southeast University.

http://dx.doi.org/10.1016/j.foar.2017.01.001

One may wonder why the construction has not adopted such a concept because in many cases, “know-how” knowledge contains results that come from experience, and such results could support an FD reasoning. In their paper, Cavalaro et al. (2012) investigate a complex construction: concrete tunnels. The latter is composed of several elements, and each element has its own tolerance limits, thereby making global construction difficult to assess.

The construction industry is moving toward a more industrialized process. The advent of lean construction in the 1990s (Koskela, 1992) was a turning point in how construction is seen. Lean construction is a philosophy adopted from the Toyota Production System, which aims to eliminate waste (physical and information) throughout the construction value chain while maximizing value to the client. Directly copying the applications from manufacturing would not be feasible because of the differences between the two industries (Tezel and Nielsen, 2013). Ballard and Howell (1993) pointed out the challenges faced by the construction industry and found that more than 40% of tasks scheduled weekly onsite were not realized. A real concern with regard to the productivity of the construction sector was raised (Park et al., 2005; Tucker, 1986).

Many studies investigated tolerance issues in construction under the lean construction perspective (Alexandridis and Gardner, 1992; Iwashita et al., 2012; Milberg and Tommelein, 2010). Milberg and Tommelein (2003) explored tolerance problems of partition walls and found that geometric tolerances related to products and processes can have negative effects on project outcomes. A proposed solution to mitigate risks is the use of maps. Milberg and Tommelein (2005) explained, “Tolerance maps are a tool for specifying, analyzing and allocating tolerances for both product and process design.”

With the changes made by building information modeling (BIM) in the way construction is designed, the construction sector should clearly consider FD and begin to incorporate this way of reasoning in various stages of design. The “as-built” concept is now investigated through BIM (Woo et al., 2010) to match the design to construction as accurately as possible while resolving design issues upstream.

2. Concept of tolerance in construction

Architectural engineering and construction introduced the concept of tolerance according to the different existing trades:

- The mason works with a +/−10 mm tolerance.
- The carpenter works with a +/−5 mm tolerance.
- Some trades have lower tolerances.

Every construction trade must respect the tolerances because they are part of the professional “know-how” and the expected quality (cf. DTU and best practices).

However, are current efforts sufficient? What is happening in reality?

The performance required for each trade corresponds to the potential performance observed in the execution phase at the worksite. In the next section of the paper, we introduce FD by following these steps:

1) Identifying the functional dimensioning challenges induced during the design phase;
2) Exploring how the experience of contractors helped envision potential solutions.

To illustrate the situation, we consider three case studies. The first one is a classic case encountered in building construction: an element designed to fit into a reservation in the wall. The second case study deals with tolerance problems related to bathroom construction. The last part investigates FD and design by using an elevator case study.

2.1. Case study 1: Window in the bay

We will consider a window in a 900 mm × 900 mm bay (Fig. 1). The carpenter has 900 mm and the mason has 900 mm for the structural work for the bay. According to 36.5 (2010); P18-201 (2004), each of the two trades have the following tolerances:

- +/−10 mm for concrete (in the extension for the bay);
- +/−5 mm for carpentry.

The results of the minimum and maximum dimensions are presented in Table 1.

The bays can range from 890 mm to 910 mm. The windows can range from 895 mm to 905 mm. This result generates a dimensioning problem. Large windows that measure 905 mm do not fit in the small bays of 890 mm; a 15 mm (10 mm+5 mm) gap exists.

Using this example, we showed that the gap between the largest window and the narrowest bay is equal to the sum of tolerances of the carpenter and the mason (10 mm+5 mm).

In a practical way, we will ask the most accurate trade (i.e., the carpenter) to dimension his work to avoid conflict with the mason's tolerances. The mason will continue to dimension the 900 mm bay while knowing that the expected produced bays could range from 890 mm to 910 mm.

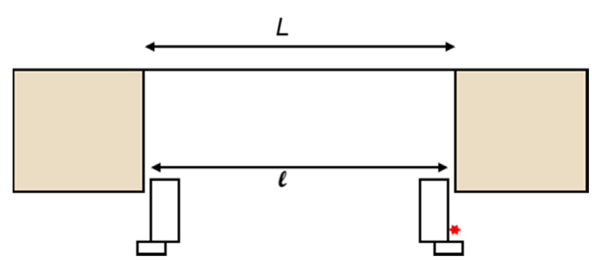

Fig. 1 Window (L) and bay's (l) dimensions.

Table 1 Minimum and maximum length for the bay and the window according to DTU code.

	Length + tolerance	Minimal length (mm)	Maximal length (mm)
Bay	L=900 +/−10 mm	L_{min}=890	L_{max}=910
Window	l=900+/−5 mm	l_{min}=895	l_{max}=905