Defining Performance-Based Design

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1. Introduction

The following article is the first in a series of articles that summarise a presentation entitled *The Contribution of the RTM to the Global Advancement of Performance-Based Design*, given by the author at the recent SFPE 2020 Performance-Based Conference & Expo, which was held in Auckland, New Zealand from 11 to 13 March 2020.

While the conference presentation as a whole focused on the broader role of the SFPE’s *Standing Committee for Research, Tools and Methods* (the so-called ‘RTM’) in advancing the implementation of performance-based design (PBD) internationally, this summary article from the presentation specifically deals with the author’s views on what qualifies as being defined as PBD.

The context for this article is a new SFPE committee which has recently been formed to develop a new SFPE standard on PBD. One of the first activities for this new committee has been to form a collective view of how to define PBD.

For clarity it should be noted that the views expressed in this article (and the original conference presentation) are those of the author alone and do not represent the formal view of the above-mentioned committee, or the SFPE as a whole.

2. Definition of Performance-Based Design

Although current performance-based design (PBD) in the field of fire safety engineering has been in existence for more than two decades in some countries, there still appears to be a lack of clarity about what PBD actually is in different parts of the world.

It is possible to speculate that this is partly due to significant differences in the building regulatory environment in different jurisdictions, which in turn has a significant impact on what constitutes standard industry practice in a particular jurisdiction.

The following definition is one possible way of defining what PBD is, in the context of performance-based fire safety engineering, namely:
PBD methods are alternative, risk-informed methodologies used to demonstrate compliance with fire safety objectives.

The author acknowledges that this definition for PBD is consciously narrow and specific while different stakeholders will often have broader goals and objectives.

3. Alternative Design Methods

As noted in the definition above, emphasis is placed on two terms - ‘alternative’ and ‘risk-informed’.

What is meant in the stated definition by ‘alternative’ design methods?

The New Zealand building regulator currently provides two prescriptive, deemed-to-comply design documents which can be used by fire safety designers to demonstrate compliance of a building design with the protection from fire clauses of the New Zealand Building Code (NZBC). Such prescriptive compliance documents are called ‘acceptable solutions’ in New Zealand, with the major one being C/AS2 [1].

If a designer designs a building to comply with the provisions of this particular acceptable solution, C/AS2, then the design as a whole is deemed to comply with the fire safety clauses of the NZBC (the ‘protection from fire’ clauses C1 to C6).

Under the stated definition, for a design method to qualify as being a performance-based design method, it must be an ‘alternative’ method to prescriptive methods such as C/AS2 in New Zealand.

In relation to prescriptive design methods, an important reason for alternative methods being needed is that most prescriptive design methods have limitations in their scope of application, beyond which the document cannot be used.

A common example of a limitation in the scope of application of prescriptive design methods is the height of the building being designed.

Figure 1 shows an extract from C/AS2, where paragraph 1.1.2.e) stipulates that “buildings more than 20 storeys high” are outside the scope of the acceptable solution.

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1 The term ‘design method’ as used in this article is a consciously broad interpretation. It could be argued that a prescriptive design solution is not actually a ‘design method’ when the design process consists of verifying compliance with a prescriptive code/standard.
While the New Zealand prescriptive design method C/AS2 is an obvious example of a design method that does not fit the stated definition, perhaps not quite so obvious as to what is an alternative design method is the New Zealand verification method, C/VM2 [2].

Again, as with C/AS2, C/VM2 is also not a performance-based design method in relation to the stated definition because it is also not an ‘alternative’ method. C/VM2 is still a deemed-to-comply design method in terms of compliance with the NZBC clauses C1 to C6.

For clarity, ‘alternative’ in terms of the stated definition does not equate to a range of choices of design methods, rather it means an ‘alternative’ to those specific methods that are stipulated by the building regulator or authority having jurisdiction (AHJ) as being deemed-to-comply with the fire safety code.

As with C/AS2, C/VM2 in turn has its own limitations of scope of application. As shown in Figure 2, C/VM2 has the same (albeit worded slightly differently) building-height limitation to that in C/AS2, namely a threshold of 20-storey buildings.
In effect, the New Zealand prescriptive design method of C/AS2 and the fire engineering design methods of C/VM2 cannot be used to confirm the compliance of buildings of more than 20 storeys in height. Instead, what is called an ‘alternative solution’ in New Zealand, i.e., an ‘alternative’ design method, must be used to design the building in question, which now fits within the stated definition for PBD.

One of the implicit reasons that prescribed design methods (in the case of this example, C/AS2 and C/VM2) place limitations on their scope of application is related to risk. Both the acceptable solution design method, C/AS2, and the verification method design framework, C/VM2, have an inherent level of fire safety risk that the New Zealand building regulator has deemed to be acceptable on behalf of New Zealand society as a whole.

Accepting the principle that the higher the building the higher the level of fire safety risk, if a designer were to apply the C/AS2 or C/VM2 design methods to the design of a building of more than 20 storeys, the designer would be exceeding the tolerable risk threshold implicit in both documents. Specifically, if a designer used C/VM2, for example, to design a 50-storey building, the design would most likely be exposing subsequent building occupants to a higher
level of risk and delivering a lower level of fire safety, relative to the risk/safety of using the document to design a 20-storey building.

4. Risk-Informed Design Methods

What is meant in the stated definition by ‘risk-informed’ design methods?

In essence, the term ‘risk-informed’ is referring to ‘probabilistic’ design methods.

It is important to differentiate between ‘deterministic’ (or ‘non-probabilistic’) and ‘probabilistic’ design methods, or more accurately, design methods that incorporate ‘deterministic’ or ‘probabilistic’ analysis methods.

The difference between ‘deterministic’ and ‘probabilistic’ analysis methods can be represented by the mathematical relationships, shown as Eqn. 1 and Eqn. 2.

**Deterministic Analysis**

\[ f(A, B) = C \]  

**Eqn. 1**

**Probabilistic Analysis**

\[ f(p(A), p(B)) = p(C) \]  

**Eqn. 2**

In the context of a simplified engineering analysis depicted by Eqn. 1 and Eqn. 2, ‘deterministic’ analysis consists of a single value for the two exemplar input parameters, \( A \) and \( B \), resulting in a single value for the output parameter, \( C \), from the application of the mathematical function, \( f \).

The ‘probabilistic’ analysis equivalent involves a probabilistic (or statistical) representation for the two input parameters, \( A \) and \( B \), resulting in a probabilistic representation for the output parameter, \( C \), from the application of the same mathematical function, \( f \).

5. Summary - Key Message

In providing a definition for PBD, and expanding on what is meant by the two definitional criteria of ‘alternative’ and ‘risk-informed’ design methods, the key message in this article is that detailed quantitative risk analysis (often termed ‘quantitative risk analysis’ or QRA) is at the core of true PBD. In other words, for the design method to be regarded as a performance-based design method, the analysis component of the design method must be probabilistic in nature.

A widespread issue in the practice of PBD is that some form of qualitative or semi-quantitative risk analysis is applied to the design in question, and it is either stated by the designer or implied that the design is a performance-based design.

For example, so-called PBD where the designer as part of the analysis nominates a high percentage reliability figure for a sprinkler system, and on that basis concludes that the design complies with the requirement of the building code, is not actually PBD. To qualify against the stated definition, a detailed QRA would need to be performed. The high percentage sprinkler system reliability figure used by the designer, is typically an upper bound of what is actually a probabilistic distribution of the reliability which in fact has a wide range of possible values.
REFERENCES
