Towards Standardization of Data for Structural Concrete: Product Data Templates

Mohamad El Sibaii[1](✉), Renan Rocha Ribeiro[1], Ricardo Dias[1], José Rui Pinto[2], José Granja[1], and Miguel Azenha[1]

[1] ISISE, Department of Civil Engineering, University of Minho, Guimarães, Portugal
mohamadelsibaii@gmail.com
[2] Mota-Engil, Porto, Portugal

Abstract. The Architecture, Engineering, Construction, and Operation (AECO) industry is shifting toward the digitalization of its processes, with Building Information Modelling (BIM) methodologies. The use of BIM in AECO industry requires the definition of data requirements for the information exchanges between stakeholders. Data definition and management present a relevant challenge for implementers and can be hindering the spread of BIM in the industry. Product Data Templates (PDTs) are essential contributions to solving this matter through standardization and digitalization of construction product data. However, there seems to be a slow uptake of initiatives that provide open PDTs for the industry to adhere to the latest PDT standards, like EN ISO 23386 and EN ISO 23387. The lack of open PDTs for concrete-based materials/products is an illustrative example of the limitation reported. In such concern, and to contribute to the discussion of PDTs in the concrete industry, this paper proposes a PDT for pre-cast concrete beams. The PDT considers several sources of information such as Construction Product Regulations (CPR), Environmental Product Declarations (EPD), Industry Foundation Classes (IFC), and in-situ and laboratory tests, among others. This PDT will help push towards the digitalization and standardisation of data for concrete elements in BIM models and facilitate their use in BIM processes, including sustainability analyses.

Keywords: BIM · Standardisation · Product Data Templates · Information management · IFC

1 Introduction

As the construction industry continues to embrace digitalization and BIM methodologies, the need for accurate digital models of construction products has risen. The creation of digital models is possible through the use of BIM object classes/instances, which are digital representations of products, systems or construction elements. They must include comprehensive information such as performance, sustainability, maintenance, and geometry [1]. The quality of BIM objects is closely linked to the quality of the associated information, that impact its usability by the various actors throughout the different phases of the design and construction processes [2–4].

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Construction product data needs to include different types of information defined by different stakeholders at different stages of the life cycle of a project. Some of the information needed is defined by the Construction Products Regulation (CPR) directive in Europe through the Declarations of Performance (DoP) that, depending on the product class, are characterized by harmonized European standards, resulting in the affixation of the CE marking. Defining and standardizing the appropriate data in the correct format in the BIM objects of these products has been particularly challenging. Indeed, BIM objects should ensure several information quality/nomenclature conditions that facilitate IFC interoperability, in addition to conforming to existing BIM object standards/guidelines [5], taking into account the information required for a specific project phase [2–6].

In recent years, several standards and guidelines have been issued to support the definition of data requirements of BIM models/objects throughout their lifecycle. As an example, reference is made to the activity of CEN/TC442 committee, which issued EN ISO 23386, EN ISO 23387, and EN17412-1 on the subjects of Product Data Templates, and Level of Information Need. However, these standards are inherently generic, not providing specific information to standardize alphanumeric data for construction materials/products and are therefore not directly applicable to day-to-day processes in the industry.

Product Data Templates (PDTs) contribute in a central way to the solution of the mentioned challenges [7]. EN ISO 23387 defines 'Data Templates' as standardized, interoperable data structures used to describe the characteristics of construction products, systems, and objects. Data Templates support the data of construction objects/products by ensuring the exchange of machine-readable information between all involved parties throughout the life cycle.

Construction with prefabricated concrete products, like beams and slabs, is gaining much attention in the industry because it is strongly associated with higher productivity and significant cost, time and quality gains [8, 9]. This is achieved as a result of improved constructability and standardization, especially when it is combined with BIM methodologies [10, 11].

In this sense, the literature holds several works on standardizing data for the industry, but no works specify exactly the data needs of BIM objects, and there is a lack of PDTs openly available for the industry for construction products that adhere to the latest standards [2–16]. This is specifically relevant for concrete-related products, even though it is considered one of the most used materials in the industry and one the most impactful in the context of sustainability [17].

In response to the presented opportunity, a Product Data Template for precast concrete beams is presented in this paper. The paper starts with an overview of PDTs with insights on existing related standards and initiatives. Then the methodology for PDT creation is discussed, and the aforementioned data template is presented.

2 PDTs: Standards and Existing Initiatives

CEN/TC442 has recently adopted two important ISO standards as EN standards in the context of PDTs: EN ISO 23386 '*Building information modelling and other digital processes used in construction - Methodology to describe, author and maintain properties in interconnected data dictionaries*' and EN ISO 23387 '*Building information*

modelling (BIM) - Data templates for construction objects used in the life cycle of any built asset - Concepts and principles'. In the context of CEN, there are also more documents/standards under development regarding PDTs that elaborate on their relation to important concepts in the construction industry like data exchange using IFC (prEN 17549-1), their role in the definition of the Level of Information Need (EN 17412-1), and the definition of sustainability information based on Environmental Product Declarations (EPDs) (prEN ISO 22057) [18–23]. Despite the reported developments, there is still little work devoted to the most recent normative framework, which relies on documents as recent as 2020 in the case of EN ISO 23386. In addition, EN ISO 23387 itself is currently under revision. In this context, it is still difficult for the industry to find sources for standard-compliant PDTs that are being used widely. Consequently, it is still usual to observe great dispersion in the amount/quality of information present in BIM model objects. Regardless of that, many commonalities within Europe allow an interesting degree of homogenization of approaches/concepts.

In alignment with the provisions of EN ISO 23386, the creation of data dictionaries and PDTs should be undertaken on a national scale, taking into account the specificities of each country's construction market. This results in varying levels of development and progress in different countries. There are some papers in the literature on PDT standardization [1–24], however, they do not make available extended sets of PDTs for widespread use [6–16]. Several initiatives, such as the UK-based National Building Specification (NBS) and Chartered Institution of Building Services Engineers (CIBSE), have produced open PDTs, but with different formats and do not yet adhere to the latest PDT standards. However, there are particular initiatives, such as CoBuilder, LEXiCON, and the SN/K 374 commission in Norway, that are working on developing PDTs that adhere to the latest standards. However, they have not yet made their PDTs openly available to the general public.

The buildingSMART data dictionary (bsDD) is an important reference, serving as a good example of a data dictionary that is open, well-structured and comprehensive. Its alignment with ISO 23386 guidelines makes it a valuable resource for organizations looking to adopt a standardized approach to data management in the construction industry [25].

Interoperability between these data dictionaries and BIM platforms/tools is crucial to achieving the reuse and harmonization of properties across data dictionaries. This can be achieved by adhering to ISO 23386 guidelines, where each definition in a data dictionary is assigned a unique identifier that serves as a link to other data dictionaries. This enables BIM applications to consistently utilize multiple data dictionaries, promoting consistency and interoperability.

On the other hand, the EN ISO 23387 standard establishes the principles and structure of data models for building objects and supports digital processes by establishing standard data structures for exchanging information in machine-readable formats. This standard is created to facilitate the use and reuse of information, by providing the structure to group the properties created according to EN ISO 23386 into data structures called, PDTs. By following the proposed data structure, it is ensured that specific information needs are addressed, such as performance data related to CE marking. It also ensures that defined properties are connected to reference documents, like standards,

that define the methods of measurement of these properties to ensure clarity between stakeholders during information exchanges.

In line with the challenges identified, this paper illustrates the process of production of data templates and discloses information about the creation of the data template for a pre-cast concrete beam, while sharing the whole data template for further discussion and improvement.

3 Product Data Templates for Concrete Products

3.1 Methodology of EN ISO 23386 e 23387 for PDT Creation

The first step in the creation of a PDT is the collection of parameters (see Fig. 1). Parameters can be collected from various sources, and therefore should be compared against each other in a single matrix to ensure that the parameters are unique. Parameters in different sources may have different nomenclature, but the same meaning. Consequently, the comparison and normalization step eliminate redundancy and repetition. Once a final list of parameters is decided upon, it is organized into categories, such as geometric data, performance data, sustainability data, etc.

Fig. 1. Methodology for creating PDT adapted from [12]

After the properties are defined and organized, the predefined structure of PDTs in EN ISO 23387 is used, where each property is linked to a reference document, and its data type, unit, and value are defined. Next, EN ISO 23386 provides a predefined set of attributes for properties and property groups, and these attributes must be linked to the properties in the created PDT. This step will ensure that the properties in a data template will be traceable in case any change occurs in the property, like a name or description change, or a change in the method it is obtained. Moreover, it will ensure its machine readability through the use of Globally Unique Identifiers (GUIDs) and the possibility to connect it to other data dictionaries through the attribute "Relation of the property to interconnected data dictionaries" (see Table 1).

Finally, once a PDT is published, it is important to establish an open line for review and comment by industry professionals knowledgeable in specific construction products and their use. The information gathered from these professionals will help improve the content of the PDTs, and keep their data up to date. The authors of this paper have been developing a platform for providing open PDTs, created following the proposed methodology, for construction products in the Portuguese context. The platform also has a page dedicated to receiving feedback from the industry, following the recommendations of ISO EN 23386 [12–26].

Table 1. Part of the list of property attributes from EN ISO 23386

Attributes list	Example
Globally unique identifier	541c4a8d2bde494a961ba90f007c79bd
Version number	1
Revision number	0
Date of version	20/05/2020
Date of revision	30/05/2020
Group(s) of properties	1751072cd43e4765b8ae071e9454eec0
Units	unitless
Status	Active
Creator's language	Portuguese
Country of use	Portugal
List of Replacing properties	n/a
List of replaced properties	n/a
Relation of the property to interconnected data dictionaries	(0QbnIV_NrAegXIFXMWPnP6, bsdd.buildingsmart.org)

3.2 Product Data Template Proposal

Our proposal includes a Master Data Template (MDT) part, common for all construction products. It includes the following data categories: general, classification, geometrical, manufacturer, and sustainability data based on the prEN ISO 22057. Then, the construction of the specific PDT part for the precast concrete beam can start to be analysed. To create a data template for an element that is made up of different products such as the precast beam, the data of those individual products must first be collected, and then their data can be nested within the data template of the final product. Yet, not all properties from the sub-products are relevant to the data template of the final product, hence, only the relevant data is to be selected. Accordingly, data were collected for the following sub-products/sub-components of the precast concrete beam: Concrete, Steel Reinforcement, and Prestressing Steel. Data was also collected for the precast concrete beam product as a whole. The following describes the method and results of creating the Precast Concrete Beam Data Template (PCBDT).

The first step of creating the data template for the precast beam was to attempt to collect as much data as possible with relevance to this product in its lifecycle. The sources considered were the data templates from NBS, property sets of the IFC, Natspec property generator, ETIM, Concrete Cement & Aggregates Australia (CCAA), and international standards related to precast concrete elements: EN 15037-1:2008, EN 13225:2013, EN 13369:2013, EN 1520:2011, and EN 1992-1 [27].

The Master Data Template mentioned above included property categories related to general, manufacturer, facility management, and sustainability. Hence, the categories that

needed developing were related to performance, with a focus on data related to CE marking, specification, and detailed geometry. The properties collected from international standards related to precast concrete beams comprised around 50% of the properties, and all these properties were under the performance data category.

Around 30% of the properties sourced from IFC went under geometry, specifications, and performance categories. The IFC has property sets related to the IfcBeam object and specifically related to precast elements, which were developed as part of the initiative IFC4precast [28]. The property sets are Pset_BeamCommon, Pset_ConcreteElementGeneral, Pset_PrecastConcreteElementFabrication, Pset_PrecastConcreteElementGeneral, Pset_ReinforcementBarPitchOfBeam, and Qto_BeamBaseQuantities. The remaining ~20% of properties were sourced from CCAA, ETIM and NBS. These sources were used to collect three categories of information which are performance, specification, and geometrical data.

Once the properties were collected, the data underwent a normalization process, where properties with the same meaning are put in a single row in the property matrix and their nomenclature compared, then one unique name is selected to represent this property in the PDT being developed (see Table 2). The selection of the name and its format follows the guidelines set by the "Building Information Modelling (BIM): Rules for the Modelling of BIM Objects" document, which is created for the Portuguese context [29].

Once the final list of properties is finalized, the properties were to be organized as per the suggested format in EN ISO 23387. Therefore, for each property in the data template, the property name, group, unit, quantity, enumerated type values, and reference document was defined (see Table 3). It is important to note that some properties may have multiple reference documents. For example, thermal transmittance can be measured using the methods in ISO 9869-1, ISO 9869-2 or ISO 9869-3. Hence depending on the entity creating and using the data template, the appropriate standard must be used as a reference document.

The final Precast Concrete Beam Data Template was created by combining the data collected for the beam as a whole object and the data collected for the sub-products: concrete, reinforcing Steel, and prestressing Steel, as well as the Master Data Template referenced in Sect. 3.1. The proposed Precast Concrete Beam Data Template can be consulted in its entirety through the following link: https://doi.org/10.5281/zenodo.7639975.

Furthermore, the structure of the PCBDT can be adapted to match the specific components of the precast concrete beam. In the proposed template the sub-components concrete, steel reinforcement, and prestressing steel were taken into consideration. However, additional sections can also be added to the template if other materials, like Fiber Reinforced Polymer, are used in the beam or if more than one type of prestressing steel is used (see Table 3).

The next step in the process is the application of EN 23386 for the data template. In this step, the attributes mentioned in Table 1 will be filled for each property in the data template. The GUIDs for each of the properties were created using an online GUID generating tool [30], the connection to other data dictionaries through GUIDs was not

Table 2. Part of the matrix of normalizing PDT properties for precast beam

IFC	EN 15037 1:2008	EN 13225:2013	EN 1520:2011	Selected property name
Strength class	CompressiveStrengthClass		compressive strength class of concrete	StrengthClass
	Ultimate tensile strength of steel	ultimate tensile strength of reinforcing steel	ultimate tensile strength of reinforcing steel	UltimateTensileStrengthOfReinforcingSteel
	Tensile yield strength of steel	tensile yield strength of reinforcing steel	tensile yield strength of reinforcing steel	TensileYieldStrengthOfReinforcingSteel
ExposureClass			exposure class	ExposureClass
	Fire resistance	fire resistance	fire resistance	FireResistance
FireRating	Reaction to fire	fire classification	reaction to fire	FireRating
		compressive strength of concrete	compressive strength of concrete	CompressiveStrengthOfConcrete

yet completed, once the existing data dictionaries in the industry do not yet define GUIDs for their properties as per the recommendations of ISO EN 23386.

Table 3. The structure of the Data Template as per EN ISO 23387

Group of Properties	Property	Unit	Description	Reference document
Master Data				
General	Name	unitless	The product name	
Geometrical	NominalHeight	mm	The vertical dimension	
Manufacturer	NetWeight	kg	Net weight excl. package	
Sustainability	InertWaste	kg	Quantity of inert waste generated	
(…)	(…)	(…)	(…)	(…)
Precast Concrete Beam				
Performance	ServiceResistanceMoment	kNm	The service resistance moment	EN 15037
Performance	FireResistance	unitless	Fire resistance class	BS EN 13501
Performance	ExposureClass	unitless	Beams exposure class	BS EN 206
(…)	(…)	(…)	(…)	(…)
Concrete Data				
Performance	StrengthClass	nominal	Classification of the concrete strength	BS EN 206
Performance	ThermalConductivity	W/(m.k)	Thermal conductivity of concrete	EN 13369
Performance	ThermalResistance	K/W	The thermal resistance of the beam	EN 13369:2013
(…)	(…)	(…)	(…)	(…)
Reinforcing Steel Data				
Performance	SteelGrade	unitless	The grade of reinforcing steel	BS EN 10080

(*continued*)

Table 3. (*continued*)

Group of Properties	Property	Unit	Description	Reference document
Performance	UltimateTensileStrengthOfSteel	N/mm^2	Ultimate Tensile Strength Of Steel	BS EN 13225
Specification	SteelCoating	unitless	coating applied to steel	BSEN1520
(…)	(…)	(…)	(…)	(…)
Data Prestressing Steel Data				
Performance	PrestressingSteelType	unitless	The prestressing steel type	prEN 10138
Performance	InitialTension	N/mm^2	initial stress of the tendon	BS EN 13369
Geometrical	MinimumConcreteCoverOfPrestressingSteel	mm	The minimum concrete cover required	
(…)	(…)	(…)	(…)	(…)

The presented data template was analysed by the authors, with support on their experience with concrete-related and prefabrication subjects, in order to filter and organize the template as well as ensure its completeness. Part of the actions taken on properties during the meetings, consultation and analysis process is shown in Table 4.

Table 4. Actions and reasons took during the PDT analysis

Property	Action	Reason
MaximumPermissibleOverhang	Added	Important for transport of element
MinimumConcreteCoverOfPrestressingSteel	Added	Essential characteristic for casting concrete with prestressed steel
SteelGrade	Added	Important for the definition of reinforcing steel
AirborneSoundInsulation and ImpactSoundInsulation	Removed	Not relevant for beams and more for precast floor elements
ShearCapacity, and ShearStrength	Removed	These properties were removed as the property "UltimateShearResistance" is included

(*continued*)

Table 4. (*continued*)

Property	Action	Reason
PartialSafetyFactorForConcrete, and PartialSafetyFactorForSteel	Removed	Not relevant after the product is manufactured, and the final performance characteristics are defined in other properties
StructuralClass	Removed	Property related to the structure, not the beam
Detailing, StirrupBarPitch, and SpacingBarPitch	Removed	The details of the beam are commonly found in external technical sheets, which can be linked-to to the property: "Documenturl"
Span	Removed	Beams can be designed for multiple different spans or can be used for any span smaller than the length of the beam
Roll and slope	Removed	Only relevant in a 3D model
ConcreteCoverAtMainBars, and ConcreteCoverAtLinks	Removed	The property ConcreteCover is defined for the least cover thickness defined in the beam, hence these properties were not found relevant
Shortening	Removed	The length of the beam considers the shortening that happens during the manufacturing of the beam, hence not found relevant after production
CamberAtMidspan	Renamed	This IFC property defines camber at midspan, but, it was decided to use Camber and describe it as camber at midpoint, once a beam might be used for smaller spans

Nevertheless, if this template is to be used by the industry, it is important to open a door of communication to other experts in the industry to receive feedback on the template and make the necessary changes. This process goes into the scope of EN 23386, where they present a methodology to obtain feedback from the industry. This process will ensure that there is a consensus on the content of the data templates and raises the possibility of integrating it into real-life projects. It is important to note that a data template can be different from one geographic location to another and the properties and the methods of obtaining them change depending on local standards. Hence, for the application of this template in the Portuguese context, it will be translated into the

Portuguese language and placed in the platform mentioned in Sect. 3.1 for consulting the Portuguese industry [12–26].

4 Conclusion

The standardization of construction product data through the use of Product Data Templates (PDTs) is crucial for improving BIM processes. This work aims to present a method to standardize and digitize data related to concrete-related products in the construction industry using PDTs. An example was presented through the development of a Precast Concrete Beam Data Template, and it is made available in its entirety through the present publication. The process of data collection and normalization was presented, as well as the process of creating the PDT in a manner that adheres to the latest PDT-related standards ISO EN 23386 and ISO EN 23387. Consultation with industry professionals to improve the data template will be possible through the PDT and consultation platform mentioned in the paper, specifically for the Portuguese industry. Standardized and digitized BIM objects data using PDTs that adhere to the latest standards will enhance machine readability, connection between data dictionaries, and automation of data comparison between different manufacturer's products, which supports sustainability by highlighting products with lower environmental impacts.

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