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Standardization for an innovative world

Miguel Angel Sanjuán [a,*], Aniceto Zaragoza [b], Juan Carlos López Agüí [a,c]

[a] Technical Director for the Industrial Quality and Environment Department, IECA, C/ José Abascal, 53, 28003 Madrid, Spain
[b] AENOR Steering Committee Member and Officemen General Director, C/ José Abascal, 53, 28003 Madrid, Spain
[c] CEN President, Brussels, Belgium and IECA General Director, C/ José Abascal, 53, 28003 Madrid, Spain

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ABSTRACT

Standardization is beneficial for society in general and for research and innovation in particular. Standardization bodies as well as policymakers should promote the use of standards as a way of disseminating knowledge, exploiting research results and reducing time to market for the "innovation". Several examples are presented here with regard to the standardization of research/innovation in the cement field. From cement manufacturing to nanotechnology applied to additives, cement and special concretes, it is possible to find good examples of innovation/research activities linked to standardization.

Contents

1. Introduction

Innovation can be defined as the "process of turning ideas into manufacturable and marketable forms" according to Watts Humphreys. Therefore, innovation is based not only on the industry's capacity but also on its ability to do things in a more efficient and simplified way. In this line, it can be said that innovation refers to radical or gradual changes in products, processes or services.

In the context of cementitious materials, innovation can be referred to as a performance improvement in efficiency, productivity, quality, competitiveness, improved properties of cements, new additions or binders, nanotechnology applications, and so on.

Standardization work is undertaken by experts from all sectors of society: Governments, industries, consumers, researchers, testing

* Corresponding author. Tel.: +34 914429166; fax: +34 914427294.
E-mail address: masanjuan@ieca.es (M.A. Sanjuán).

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laboratories and other stakeholders. This procedure allows standardization bodies to pick up quite early on current innovative developments and in any field whatsoever including valuable insights into the real properties of products and sources. This means that standards in many cases help good ideas to become a reality by bringing them into the global market.

Standardization bodies actively support innovation in all its sectors. As a response to market demand, they create working groups to facilitate exchange of information and to identify further standardization needs in all innovative aspects and fields.

Standards have contributed to the growth of the economy and productivity throughout history ensuring interoperability of products and services as well as making competition better and the dissemination of innovation easier and faster. Therefore, from support to innovation, the speed-up in the dissemination and adoption of technological standards contributes to a better world.

1.1. The European example

Europe, in particular, is paying increasing attention to innovation issues as revealed in the European Commission Communication "Towards an increased contribution from standardization to innovation in Europe" [1], the Council Conclusions on Standardization and Innovation [2] and the Competitiveness Council held on December 4th, 2006, which addressed in its conclusions the subject of innovation and stressed the need to enhance the European standards-setting system. Then, the Council emphasized that efficient support for innovation was an integral part of the Lisbon Process [3]. In consequence, the implementation of an innovation strategy is necessary and nine strategic priorities at EU Level were defined. One of them was "to create a pro-active standard-setting policy". In this line, the CEN has created the working group on *STA*ndardization, *I*nnovation and *R*esearch (STAIR) to provide strategic advice to the Technical Boards relating standardization with innovation. STAIR promotes that standardization on innovation projects must be considered during all process of research projects.

A recent Spanish study [4] has shown that standards not only contribute positively to improve product quality and process improvement but also have a strong positive effect on safety and environmental aspects. Some of the parameters obtained in this study for the construction sector are summarized in Table 1. As can be observed, the indicators for safety, the environment (the optimization of raw materials and energy use and environmental monitoring) and competitiveness represent about 3 in 4 which means they have a significant influence. However, the dissemination of innovations is still below the average in other industrial sectors (2.5 compared to 2.8). Fig. 1 shows clearly a comparison between the construction sector with regard to all of them.

Table 1
Effect of standardization on different parameters in the construction sector (mean values: 1 — insignificant and 4 — very important).
[4].

Industrial sector	Safety	Raw materials and energy use optimization	Environmental monitoring	Product variety on the market
Construction	3.1	2.9	2.6	1.9
All sectors	2.9	2.5	2.7	2.0
Industrial sector	**Competitiveness**	**Reduction in time spent looking for information**	**Dissemination of the innovation**	**Product differentiation on the market**
Construction	2.8	2.3	2.5	2.9
All sectors	2.9	2.6	2.8	2.9

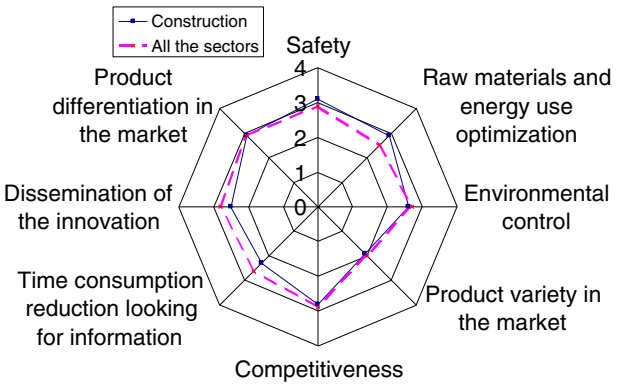

Fig. 1. Role of the standards: comparison between the construction sector with regard to all of them.

2. Standardization regarding innovation

The results of research projects as well as data coming from good original ideas represent invaluable sources of information for standardizers while, on the other hand, researchers need to have access to standards.

The standardization activities themselves may generate the need for additional research, such as pre-standardization studies to develop test methods for a product, setting of durability indicators and so on.

2.1. The role of the standardization bodies

Standards can be decisive for commercial success, by helping to:

- Increase demand for innovation activity.
- Ensuring interoperability in order to avoid the emergence of multiple standards that confuse the global market.

Thus, standardization bodies must (Fig. 2):

- Enhance standard-setting systems. The current standardization system has to adapt to the needs of fast-moving markets, especially in services and high-tech products.
- Work in consultation with industry and all other relevant stakeholders, to define proposals for action to be taken by appropriate bodies for reforming and streamlining the system.
- Analyze the role of standardization in research and new fields of technology. Standardization has to be considered during all stages of a research or innovation project.
- Investigate how to integrate standardization aspects into RTD projects. Many research projects deal with issues such as interoperability of technologies, defining specific techniques that may need to be included in standards, etc.

2.2. The benefits of standardization with regard to innovation

Standardization contributes to greater access to markets for innovative solutions and new technologies, thus increasing the competitiveness of organizations. It also contributes to the protection of the environment and helps to ensure safety with regard to innovative technologies, as well as cost savings. Standardization is a way of networking with other researchers, industries and other stakeholders such as suppliers, customers and regulatory bodies for future research and innovation projects. It can be said that the inclusion of all interested parties in framing the rules relevant for future research is a matter of the greatest interest.

Policymakers realize that standardization contributes to economic growth and increases international competitiveness by means of a faster and broader dissemination of innovations and enhanced productivity.

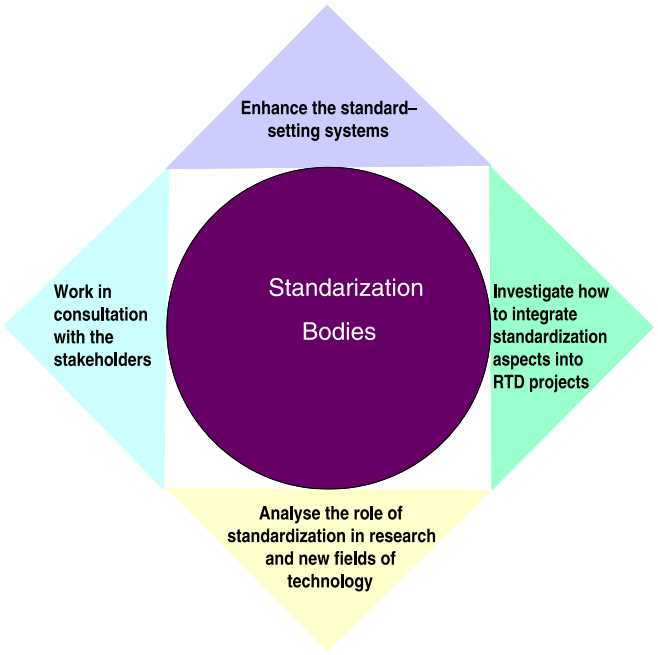

Fig. 2. Role of the standardization bodies with regard to innovation.

It is evident that standardization leads to a reduced time to market for the innovation and increased market share as well as promoting the acceptance of innovations by customers and in public procurement procedures. In the process of assessing new technologies and products, it is essential to ensure the interpolarity of in-house technologies with complementary technologies in order to be compatible.

Table 2 shows some examples of how standards have contributed to national economic growth measured by means of the Gross Domestic Product (GDP).

2.3. Research, innovation and standardization

Researchers should recognize that standardization contributes to the dissemination of knowledge in addition to scientific publications and patents, as standards represent a valuable part of the state of the art in science and technology, among other fields. They should also consider standards as a way of exploiting research results, including intellectual property rights, which are integrated into standards. In this line, they could maximize the practical application of research results by transferring the knowledge into marketable products. A clear consequence could be the enhancement of recognition and reputation.

Table 2
Comparative study on the contribution of standards to economic growth. [4].

Country	Author	Period	ΔGDP (%)	Standards contribution (%)
Germany	Jungmittang/Blind/Gurpp (1999)	1960–1990	3.3	0.9
France	Hakima Miotti (2009)	1950–2007	3.4	0.8
U.K.	DTI (2005)	1948–2002	2.5	0.3
Canada	Haimowitz and Warren (2007)	1981–2004	2.7	0.2
Australia	The CIE (2007)	1962–2003	3.6	0.8
Denmark	CEBR (2007)	1966–2003	–	Negligible
Spain	IEE	1964–2008	3.40	0.9

For instance, we can say that Dmitrii Ivanovich Mendeleev was a great innovator in his time. He published the first periodic table of the atomic elements in the first edition of The Principles of Chemistry in 1868. This table was based on properties which appeared with some regularity. Mendeleev called the chapter on the periodic law "Similarity of Elements and Their System". The third edition which appeared in 1877, included ekaaluminium (Ea) (re-named as gallium when discovered), the first of the elements to be discovered after Mendeleev had predicted their existence. In the fourth edition in 1882, Mendeleev first mentioned the discovery of ekaboron (Eb) (re-named scandium when discovered), and so on. Mendeleev noted gaps in the table, and predicted that as-of-yet unknown elements existed with properties appropriate to fill those gaps (Table 3). The four predicted elements, ekaboron (Eb), ekaaluminium (Ea), ekamanganese (Em) — technetium, and ekasilicon (Es) — germanium, proved to be good predictors of the properties of scandium, gallium, technetium and germanium respectively, which each fill the spot in the periodic table assigned by Mendeleev.

Finally, researchers should realize that patents may be licensed by referencing them into standards and thus revenues can be increased thanks to the shorter time to access them by other stakeholders.

3. From R&D+I to standardization

The best technical solution does not always prevail over the rest on the market. For instance, even though the Betamax video system was better than VHS, it was ultimate the latter that prevailed over Beta in the market. The important contribution of cement producers to standardization in Europe has promoted the standardization of new cements and new binders. This enables the concrete mix designer to choose a wide variety of cements integrated within the CE-marking framework. Nowadays, ternary cements (CEM X) are being developed by the CEN/TC 51 "Cements and lime for construction" and supersulfated cements have recently been standardized (EN 15743). These innovative proposals will allow the use of these binders on the European market. Following these examples, some other new binders will be able to follow a similar route to enter real markets. Firstly, an initial research stage is addressed to develop new cements and, secondly, a standardization stage to cover the main requirements of the Construction Products Directive (CPD) (Fig. 3). A product standard is an easy way to spread knowledge about standardized products, also helping extend its use. By

Table 3
The first periodic table of the atomic elements (first edition of The Principles of Chemistry in 1868).

The first periodic table of the atomic elements in 1868					
I	II	III	IV	V	VI
.	.	.	Ti = 50	Zr = 90	? = 180
.	.	.	V = 51	Nb = 94	Ta = 182
.	.	.	Cr = 52	Mo = 96	W = 186
.	.	.	Mn = 55	Rh = 104.4	Pt = 197.4
.	.	.	Fe = 56	Ru = 104.4	Ir = 198
.	.	.	Ni = Co = 59	Pd = 106.6	Os = 199
H = 1	.	.	Cu = 63.4	Ag = 108	Hg = 200
.	Be = 9.4	Mg = 24	Zn = 65.4	Cd = 112	.
.	B = 11	Al = 27.4	? = 68	Ur = 116	Au = 197?
.	C = 12	Si = 28	? = 70	Sn = 118	.
.	N = 14	P = 31	As = 75	Sb = 122	Bi = 210
.	O = 16	S = 32	Se = 79.4	Te = 128?	.
.	F = 19	Cl = 35.5	Br = 80	J = 127	.
Li = 7	Na = 23	K = 39	Rb = 85.4	Cs = 133	Tl = 204
.	.	Ca = 40	Sr = 87.6	Ba = 137	Pb = 207
.	.	? = 45	Ce = 92	.	.
.	.	?Er = 56	La = 94	.	.
.	.	?Yt = 60	Di = 95	.	.
.	.	?In = 75.6	Th = 118?	.	.

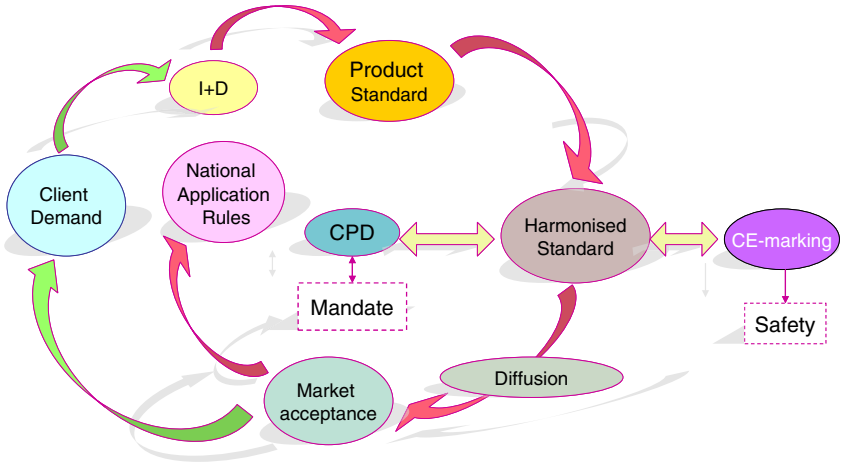

Fig. 3. Scheme showing the steps followed in new European cements such as CEM X.

contrast, in the United States of America the most common standard is the ASTM C 150 based on performance requirements. This standard does not allow additions to be mixed with the clinker. A newer standard ASTM C 595 started to include some possible additions in Portland cement, but it is not widely employed.

R&D+I is not only dedicated to product innovation, but also to developing innovative processes that facilitate such benefits as cost reduction, higher quality, and so on. The Best Available Techniques (BAT) in the European cement manufacturing sector is a good example.

Summing up, it can be said that standardization has been an effective and efficient channel for knowledge transfer regarding new cements, yet many research institutions have neglected this channel. Therefore, this poses interesting challenges for researchers, who must go from classical innovation schemes to market innovation ones or even more, they have to think of sustainable innovation (Fig. 4). Finally, Fig. 5 shows a modern model for product development, starting from the original idea to market implementation of the products, in which standards play a key role.

In order to integrate standardization into research and innovation projects and programs, it is necessary to take into account existing standards when proposing new programs. Also, it is quite convenient to consider the potential of standards as a mean to disseminate the results of research and innovation projects, including intellectual property rights, towards marketable product and process innovation activities and to consider performance indicators when evaluating the outcome of research and innovation programs (Fig. 6).

To overcome the various obstacles that may be encountered between research/innovation and standardization, a number of issues need to be addressed, such as a general lack of knowledge about the role and benefits of standardization and insufficient incentives and resources, including time and money, for researchers to manage a standardization project. Thus, the potential for standardization processes to promote the effectiveness and efficiency of research and innovation processes has not been fully exploited by researchers, innovators, and other organizations involved.

4. Best practices in the cement field

Cement standards appeared at national level at the beginning of the last century to cover strength, physical and chemical requirements or performance issues. Previously, all these requirements were specified in individual documents called "*Pliegos de Condiciones*" in Spain, "*cahiers des conditions à remplir pour l' admission des cements*" in France [6], and so on. Later, national standards on Portland Cement appeared all over the world. This early process of standardization favored the expansion and improvement of cement around the world.

4.1. Cement manufacturing

Innovations in Portland cement manufacturing are related to new available technologies to produce high quality cement with the most efficient means starting from raw material preparation to the kiln system to transporting the final product. In this sense, important progress has been made in material processing, energy reduction, environmental improvements, clinker chemistry, instrumentation and safety. Standards are being developed for all these topics.

4.2. Nanotechnologies

Standardization documents in nanotechnology will able us to have an internationally agreed terminology, measurement methods and characterization. For instance, the impact of modeling for construction chemistry is believed to help achieve a sustainable future rapidly and also optimize the processing of cement and the emergence of new products by means of nanotechnological studies.

In this line, the promotion of high density C–S–H gel could lead to lower CO_2 emissions and lower energy consumptions [7]. Other important "engineering properties" like creep and shrinkage seem to be related to the movement and interactions of "colloidal particles" [8]. Also, research into cement hydration and 3D microstructure development using an integrated approach based on non-invasive experimental methods and numerical modeling (CEMHYD3D, HYMOSTRUC-3D, μic, etc.) follow the hydration of cement grains and resolve their microstructure. But if we want to change these properties, we need to "resolve" the nanostructure (Fig. 7).

In conclusion, it can be stated that nanotechnology is one area in which the recent development of standards had a clear effect on assisting growth. Standards allow for the more careful specification of material and so international standardization committees such as ISO TC 229 "Nanotechnologies" set up in Bordeaux, France, in 2008 are quite necessary.

4.3. Sulfate resisting cements

European Standard EN 197-1:2011 includes sulfate-resistant cements for the first time. This standard as well as the North American ones includes restrictions on C_3A content in clinker determined by using the Bogue equations.

While in USA several performance standards are under development to test sulfate-resistant cements. (ASTM C452 and ASTM C1012), there is currently no performance standard in Europe.

However, Nanocem is working on this topic in Europe and it is expected that the European Standardization Body (CEN) could develop

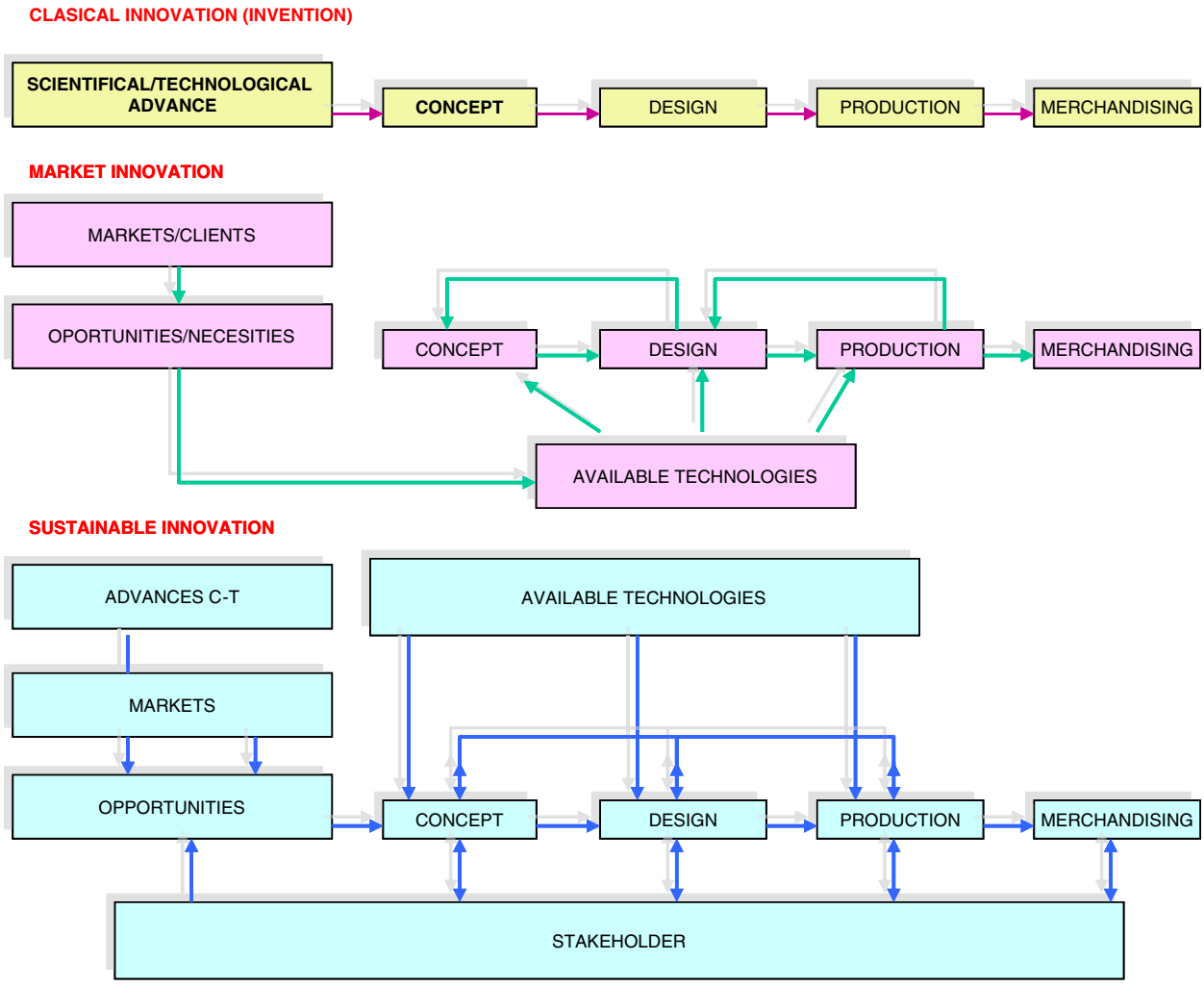

Fig. 4. From classical to market and sustainable innovation.

a standard working in connection with this European consortium. This is a good example of research co-operation between research and standardization.

4.4. Blended cements standards

One of the main issues for future standards is the increase in additions to Portland cement composition (Fig. 8).

While Europe is increasing the replacement of clinker by additions in the common cements of the European standard EN 197-1:2011, blended cements are not popular in North America and they prefer to incorporate the addition directly to the concrete. However, the ASTM standards are increasing the amount of additions to be used in cements. For instance, ASTM C150 allows up to 5% limestone to be used in Portland cement from 2004.

In Europe, a group called CEN/TC 51/WG 6/AHG-CEM X is developing a new standard considering cements with a very high amount of several additions.

4.5. High performance concretes

One of the most important innovations in recent years has been the introduction of polycarboxylate ether (PCE) based superplasticizers. These additions have been critical in the achievement of high performance/strength concretes. By manipulation of their structure, their performance can be modified in relation to cohesion, workability, rate of strength development, etc. Therefore, the possibility is open for additions to be tailored to specific applications as a key point of innovation for the future.

Cements containing silica fume (CEM II/A–D) are quite often used in high performance concretes (HPCs) and ultra-high performance concretes (UHPCs) filling the space between the cement grains and increasing their compacticity. For instance, Reactive Powder Concretes can reach 800 MPa in compression and their service life is significantly higher than that of normal concretes as a direct consequence of their very low porosity (Fig. 9) [9].

4.6. Self-compacting concretes

Self-compacting concretes were developed in 1988 in Japan [10]. The uptake of self-compacting concretes in Europe has been very rapid and several standards have appeared in relation to this new material. This is a good example of how researchers should engage in consultation work with the industry and all other relevant stakeholders.

4.7. Photocatalysis

The addition of TiO_2 particles produces a photocatalytic effect when added to concrete containing white cements [11]. This is another route for innovation by the addition of particles leading to new functions in

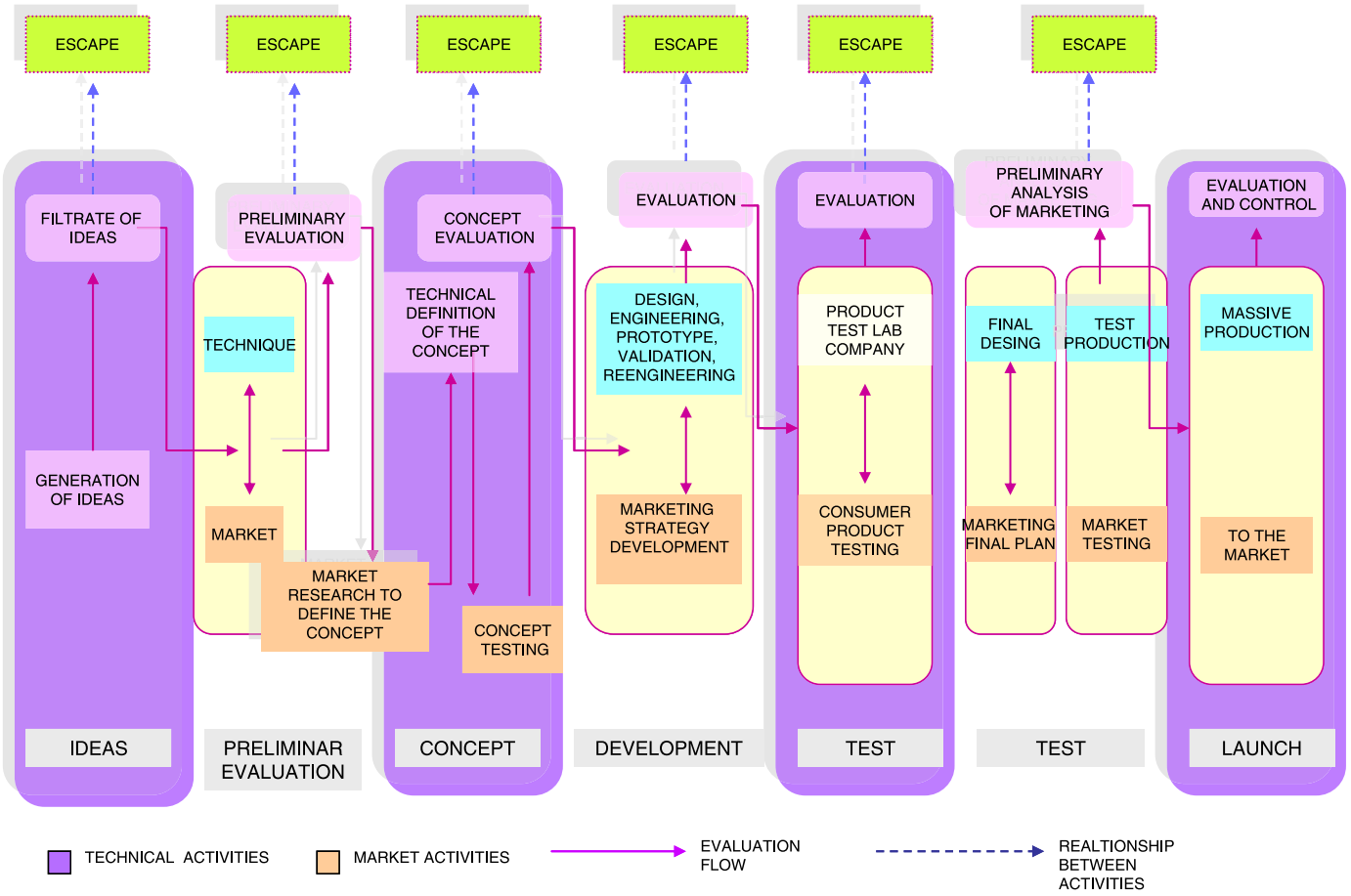

Fig. 5. Model for product development.
Source: Cooper, R.G. (1983): A process for industrial new product development. IEEE Transactions on Engineering Management, vol. 30, no. 1, pages 2–11.

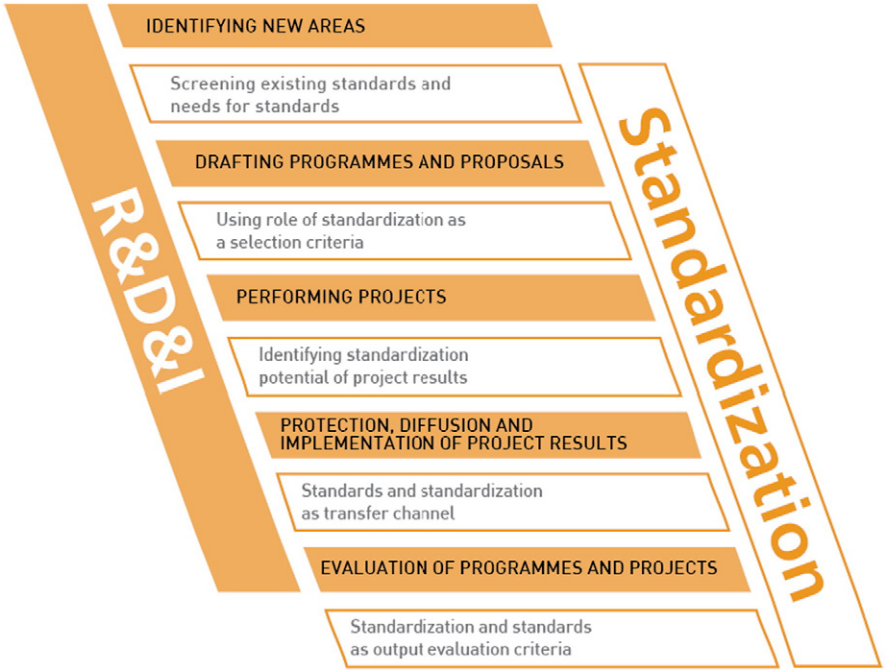

Fig. 6. Standardization at the service of research and innovation.
[5].

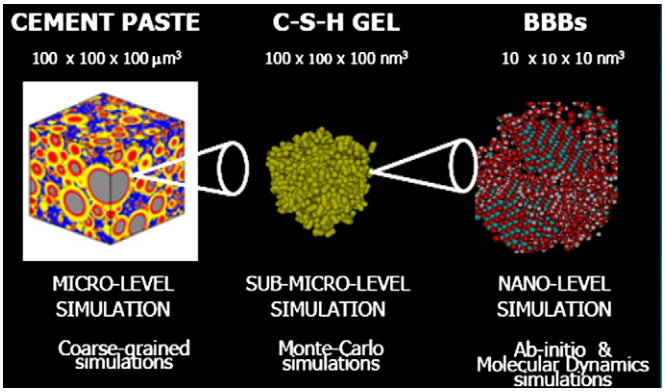

Fig. 7. COmputationally Driven design of Innovative CEment-based materials, CODICE. [7].

concrete preventing the build up of organic growth, preserving the clean appearance of the concrete for longer and breaking down NO_x and contributing to pollution reduction.

Standardization work on photocatalysis and its applications started in 2007 at the request of researchers. Their analysis had highlighted the need to define standards to measure the performance of photocatalytic processes in order to facilitate possible industrial developments. This initiative shows the interest of bringing together the worlds of research and standardization to add value to innovative solutions by establishing standardization documents. A European Technical Committee was set up in 2008 and should, in the next few years, produce standards that will speed up the development of these technologies.

4.8. Contributing to the environment

Sustainability is believed to be an important driver for future innovation, not only in Portland cement manufacturing as shown in 4.1, but also in improving the use of known additions and developing new cementitious materials with lower environmental impact. In this line, by defining common terms and definitions, technology increases comparability and transparency of products and end-user confidence in them. This also leads to reduced investment costs.

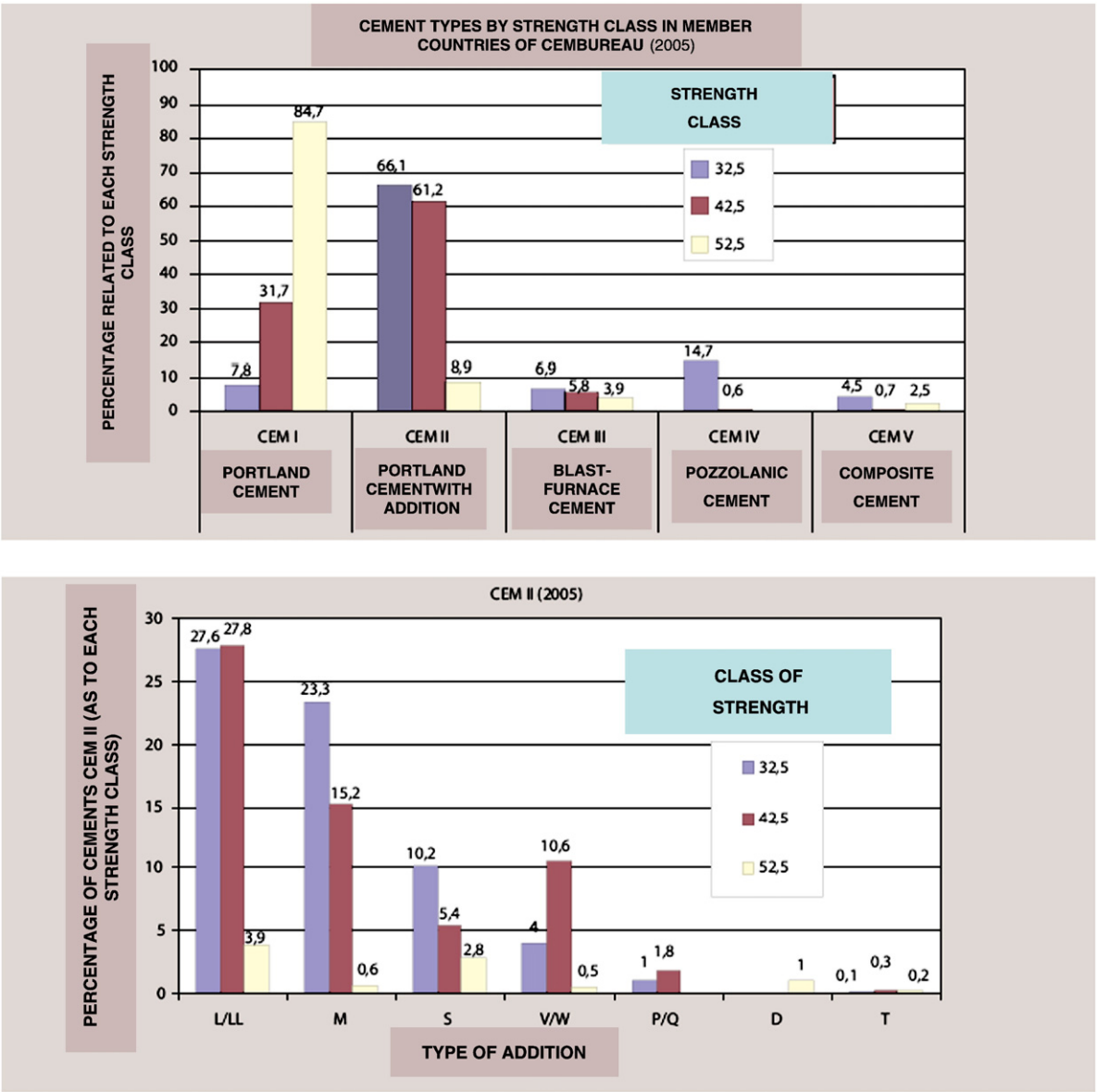

Fig. 8. Additions in European cements.

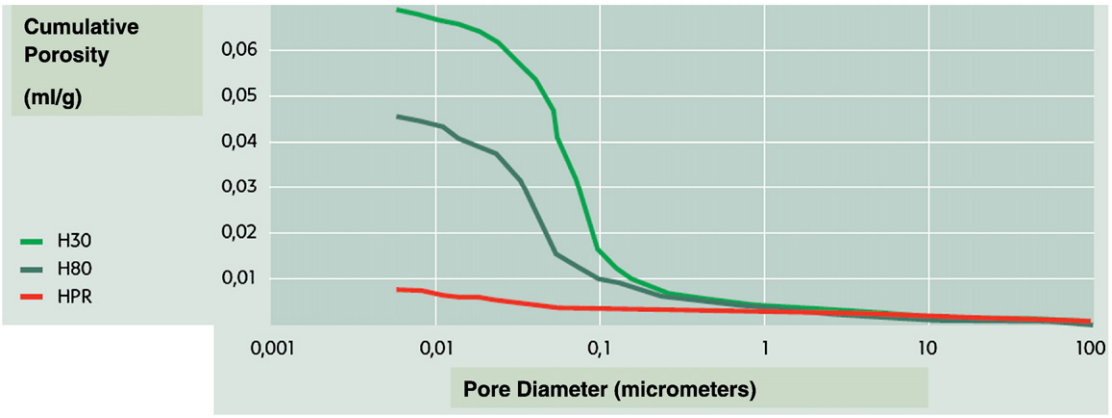

Fig. 9. Reactive powder concrete porosity.
[9].

5. Conclusion

Standardization bodies must be capable of supporting and responding to innovation by looking for common ground and a more integrated approach to standardization. Standardization covers all innovative fields of the economy. Applying protocols for product evaluation will also remove a considerable barrier to innovation. Researchers and industries are convinced that standardization will supply a strong foundation to enable technology to move forward. Particularly, in the field of cement manufacturing and research, good examples can be highlighted.

Standardization bodies need the support and collaboration of research organizations and private enterprise, as well as researchers. This means that, when the research activities are conducted by publicly-funded research organizations, e.g. universities, more public funding would be required to support any related standardization activities; since innovation activities are closer to the market, supporting standardization activities should fall on funding sources in private industry.

On the other hand, the standardization bodies in the field of research and innovation must seek the inclusion of standardization aspects in R&D+I projects and identify projects needing standardization and take up new standardization opportunities resulting from research and innovation.

Innovation in the field of cement production and research is implemented in some cases through standards. Ultimate generation additions, high-performance concretes, self-compacting concretes, self-cleaning concrete and so on are new cementitious products that are being standardized.

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