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7th Scientific-Technical Conference Material Problems in Civil Engineering (MATBUD'2015)

Material problems in civil engineering: ideas-driving forces-research arena

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Abstract

The paper presents the evolution of the MATBUD conference and discusses the driving forces of research in the field of building materials. The paper attempts to interpret the trends in relation to the development of building material engineering. The approach adopted here is the investigation of the relation between material model and performance model as well as main drivers of building material research: idea, performance, research tools development, application and technological evolution.

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Keywords: building material; building composite; building material engineering; reasearch driving forces; material model; performance model

1. Introduction - great hopes and great expectations

The paper is the result of a long discussion between authors. During the discussion we have tried to impersonate our official functions at this time: the co–chairs of the "MATBUD'2015" Organizing Committee (I. Hager, T. Tracz) and chair of the Scientific Committee (L. Czarnecki) of the Conference. Finally, we have agreed that the MATBUD is always a trial - (re)reading (with comprehension) the contemporary definition of Building/ Construction Material Engineering. Everything is from something; every structure is from some building materials. Building Material Engineering is focused on the relation "microstructure – properties" and how to use it in material

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designing, manufacturing and building material selection for a given application. The MATBUD Conferences were giving unique opportunities to define the current status between Material Models and Performance Model and to analyse the progress (Fig. 1).

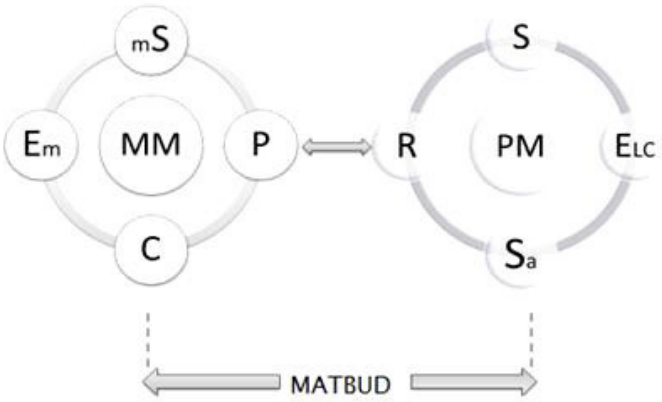

Fig. 1. Relation between Material Model, MM and Performance Model: P – properties, mS – microstructure, Energy (material manufacturing), C- Components; R – requirements, S – Structure, E_{LC} – Energy (life cycle), S_a – Serviceability.

There are several factors which mark out Civil Engineering and make that research arena particularly attractive (and of significance from the point of view of economy):

- construction consumes annually more than 40% of the overall world production of materials and energy. It is universally expected that the discipline which uses such a lot of matter should be based on the grounds and stem out of scientific rudiments. Implementing the principles of sustainable development in construction is just a necessity [1];
- there is no other discipline in which final products have their life time longer than the designer's life expectancy. Very peculiar attributes of this applied science are focused on durability and reliability;
- there is some particular fascination in the fact that "the dimension of interest" (Fig. 2) in Civil Engineering covers 15 ranks from nano – (10^{-9}) until macro – structure (10^{3}) and in consequence research objects are very diverse in complexity (Fig. 3).

In this context an imponderable value of important should be mentioned. Hugo Steinhaus (1887 – 1972) founder of the Lwow School of Mathematics preached that "Mathematics medicated between spirit and matter". Home building is a very apt exemplification of this belief. Following Hardy Cross [2], we can say that: "the glory of adoption of science to human needs is that of engineering".

There are chances and challenges. The question arises how the MATBUD will reply or contribute to reply to the challenges. The aim of the paper is an attempt to prepare a draft about the matrix: driving forces – research area. There is no ambition to define the contemporary paradigm in Civil Engineering.

It finds its reflection in the 86 Conference papers categorized into 5 sections:

- Material modelling and new test methods,
- Special and new generation concretes,
- Mineral additives and organic admixtures
- Polymers and asphalt – properties, modification, behavior .
- Ecological, historical and economical aspects of building materials.

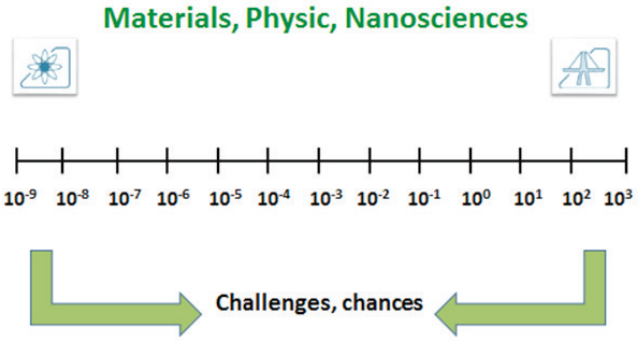

Fig. 2. Schematic illustration: "dimension of interest" in the Civil Engineering.

We believe that it allows identification of future research needs and priorities with relevance to Building Material Engineering. Certainly, it is impossible to predict the future which will become reality. However, it is possible to predict the future that may become the reality. The paper attempts to capture the "preliminary" outputs of the MATBUD'2015 in a way that might help interpret trends in relation to development; to outline the direction of further discussion. The approach adopted here is limited to two terms: "drivers" and "research area". The choice of the drivers and the research area based on the 7th MATBUD data and the author's experience is to some extent subjective and arbitrary. The limitations are acknowledged. The goal is always similar: how we do manage with building materials in the 21st century? There are expectations for:

- new arrangement of the research facts,
- new understanding of the nature of materials,
- thrust for further development,
  - in theory,
  - in application.

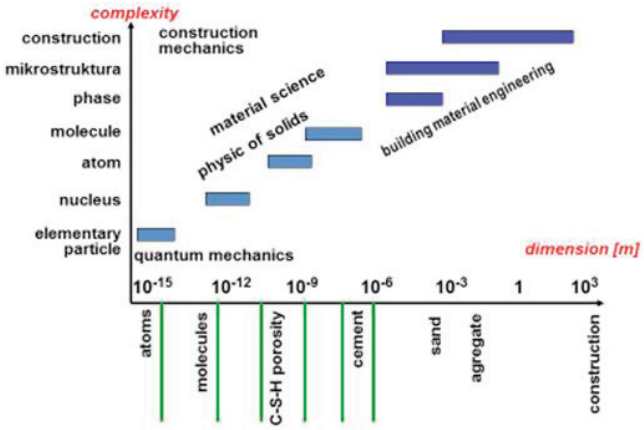

Fig. 3. Schematic illustration "complexity vs. dimension".

2. Background - reflections from the past

The 7th Scientific-Technical Conference on Material Problems in Civil Engineering (MATBUD'2015) took place at Cracow University of Technology, Poland, between 22th and 24th June 2015. It was the seventh edition of this conference, traditionally organized by the Chair of Building Materials Technology and Structure Protection, Institute of Building Materials and Structures of the Faculty of Civil Engineering at Cracow University of Technology.

The Conference was hosted by Cracow University of Technology, founded in 1945 and celebrating its 70th anniversary this year. Like in 1996, 1998, 2000, 2003, 2007 and 2011, the meeting was aimed at getting together researchers, scholars and PhD students representing all areas of Civil Engineering and Building Materials Engineering. The main focus of this Conference were several areas of the Materials Science Engineering: development, processing, evaluation, applications, and performance of construction materials in civil engineering, properties of contemporary cement composites, innovative materials in civil engineering application (including nanotechnology), polymer building composite materials, timber and wood products, NDT in civil engineering, repair, renovation and strengthening of buildings and civil engineering structures, modernization and revitalization of historic structures, fire behaviour of materials, sustainable building materials and technologies and, finally, the problems related to materials in European standardization.

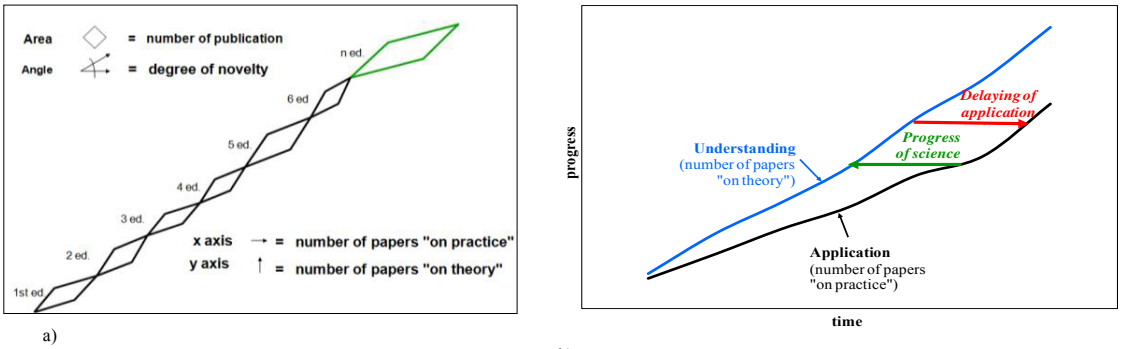

Fig 4. a) Expected trends of conference development, b) "Understanding" ahead of "application" in the light of MATBUD's results.

In Fig 4 the live curves presenting the evolution of MATBUD from 1996 to nowadays. Number of theoretical and practical papers was presented. Considering the MATBUD's life curve (Fig. 4) we could be optimistic; for 20 years the number of papers has always been reasonable and the degree of novelty quite impressive. Till now we have been constantly observing the "progress of science" outdistance the "application"; in other words, *understanding* is always ahead an *application*. However, it should be stressed that this reasoning is restricted to numbers.

3. External and internal driving forces versus keywords

The driving forces are those factors (external and internal) that have the greatest influence on the given activity outcomes [3, 4]. The proper recognition of driving forces is always verified by the future and, due to that, it is uncertain and risky. Among the external global driving forces [5] which significantly affect Building Material Engineering development we could include the following: *sustainable development* and *nanotechnology* - which have become the dominant direction of technology since the beginning of the century. *Continuous demand/expectation for innovation* should also be included into the global driving forces. In consequence the meaning of Sustainable Concrete has been defined [6] and somebody could find reasoning [7] that nanotechnology

is a chance for the future of concrete. Demand for innovation is the fundamental element of the so-called the *Prosperity Cycle* [8]:

- Ideas create: Innovations,
- Innovations create: Jobs,
- Jobs create prosperity:
- Prosperity creates the possibility to maintain the cycle (return to ideas)

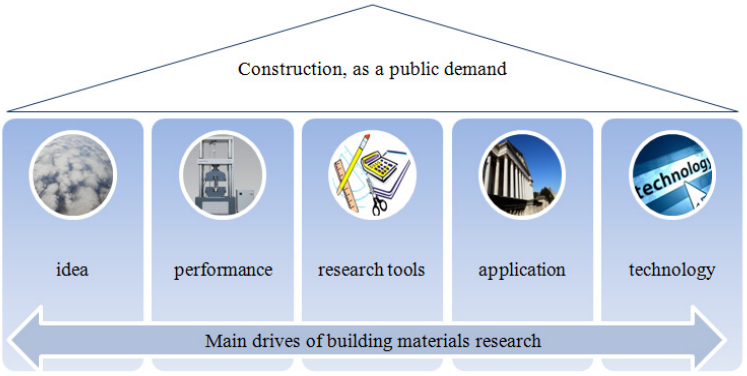

Fig. 5. Main drivers of building material research.

Table 1. Main drivers and key-trends.

Driver		Key Trend
Main	**Sub: MATBUD'2015- examples**	
Idea	Sustainability [9, 10, 11]	Demand for sustainable materials and structure
	Durability [12, 13, 14, 15]	Demand for durable (materials) and structure
	Synergy [18, 17]	Synergy between various ingredients; the phenomenon still not entirely recognized and used.
	Self-service materials [18, 19]	Demand for self-service composites , e.g. self-repairing, self-cleaning, self- compacting
	Smart material [20, 21]	Demand for materials with performance controlled by external stimuli
Application	Special concretes [41, 42]	Demand for properties improvement; material specialization
	Industrial floors / pavements [22, 13]	Demand of lower shrinkage
	Shielding concrete [21, 36, 41]	Weakening of neutron transport
	Repairing, strengthening [30]	Demand of improving mechanical properties of the structural element
	Sealant and joints [46, 47]	Sealing and ensuring continuity
	FRC [24]	Demand of higher toughness and improving performance in tension
Performance	Adhesion [25]	Demand and possibility for tailor- made performance with properties control
	Crack resistance [22]	
	Tensile/compressive strength	
	Viscoelasticity [27, 28]	
	Freeze -thaw resistance [12, 14]	
	Fire resistance [28, 29]	
	Thermal performances [10, 31]	
Research tools	Material modelling [32, 33]	A base for research development
	Microstructure/interfacial level [35, 36]	
	New test methods [44, 48]	
Technology	Solid state technology [28, 37]	How to do better ?
	Biotechnology [49]	
	Nanotechnology [20, 39]	

The internal driving forces are spread up to the material science paradigm: *microstructure – property relationship* (compare Fig. 1). Five drivers have been selected here (Table 1). According to the potential impact, they have been categorized as follows (Fig. 5): IDEA (sustainability, durability, synergy, self-service materials, smart materials), APPLICATION (repairing, shielding concrete, pavements, sealants), PERFORMANCE (adhesion, crack resistance, viscoelasticity, freeze-thaw resistance, fire resistance), TECHNOLOGY (solid-state, bio-, nano-), RESEARCH TOOLS (material modelling, microstructure analysis, innovative test methods). The above keywords are included to indicate the topic. It is worth emphasizing that some ideas have had the character of an objective imperative: *sustainable material and structure* is a civilization necessity and fundamental requirement of the European Construction Product Regulation, CPR – UE 305/2011, also *construction durability* is a fundamental requirement, according to the CPR.

The 7th MATBUD gathered 86 papers prepared by 180 authors. The authors characterized their topics in the set of more than 700 keywords. Obviously, it is evidence of great diversity. From the other point of view, it is the evidence of how rich and universal MATBUD research arena is if it needs more than seven hundred keywords for characterization. Some of the keywords (Fundamental Keywords) are repeated (Tab. 2) among various papers more than 5 times and they occur in the text of all papers more than 1 thousand times (concrete – 2.7×10^3, cement – 2.5×10^3). It is of interest that Authors stressed more frequently research objects (cement, concrete, aggregate…) than research subjects (mechanical strength, durability, shrinkage, …)

Table 2. Fundamental keywords.

	Keyword	Frequency of occurrence	
		as a keyword	in the text, $\times10^3$
Research object	Concrete	39	2.70
	Cement	23	2.51
	Air entrainment	10	0.94
	Mortar	9	0.78
	Aggregate	9	0.66
	Polymer	7	0.21
	Composite	5	0.18
Research subject	Mechanical Strength	13	1.64
	Durability	8	0.39
	Shrinkage	7	0.21
	Corrosion	7	0.20
	Hydration	6	0.27
	Resistance	5	0.41

The given keywords, that were identified as the most frequently used, the MATBUD'2015 looks rather traditional. The "concrete and the environment" seems to be the main topic of the MATBUD '2015 researchers and their investigations. In Fig. 6 the keyword cloud has been developed based on the individual authors' papers. We can discern that the most common keywords were: "concrete" with 39 appearances, "cement" with 23 appearances, "strength", as the main concrete property, 13 appearances and "aggregate" 12 appearances.

4. Generalization of MATBUD'2015 outcome

In the light of key words the MATBUD 2015 looks rather traditionally: “concrete and surrounding …..” (Fig. 5). It could be deduced that the scientific interests in the field of building materials correspond to the most widely used material in the world – concrete. The possibility of tailor-made performances of this material as well as its wide applications fully justify this interest. However, we need to keep in mind the need to ease the material’s

environmental impact and continuous work to find alternative binders, replace Portland clinker with waste materials - all solutions must be investigated as an approach to tackling concrete's CO_2 emissions.

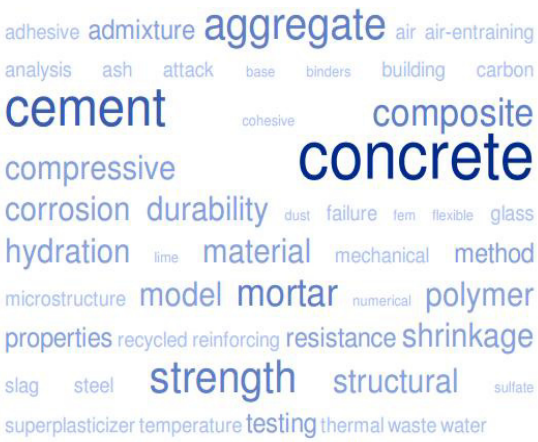

Fig. 6. MATBUD'2015 keywords cloud.

If we analyze the papers more deeply it will occur that the research subject is not just concrete, but always "better concrete" tailoring to the application, with very tune up performance. It sounds like a "*performance look*"`. It seems that just *MATBUD 2015* is the place where the idea of *performance look* comes into play. It is very important message. In this context will be useful to refresh that idea is not new. Shortly it means, that not "material nature – components" are important but technical characterization – technical properties are decisive factor. Already in 1925 – almost one hundred years ago – the US Building Code has said: *"Whenever possible, requirements should be stated in terms of performance, based upon test results for service conditions, rather than in dimensions, detailed methods or specific materials. Otherwise new materials, or new assemblies of common materials, which would meet construction demands satisfactorily and economically, might be restricted from use, thus obstructing progress in the industry."* It is still valid and of significance. How to define performance of contemporary building/construction materials (included recycling and other sustainability factors) – it is *hot task* in the Civil Engineering research front. Some studies are very spectacular addressed – relevant to the *specific technical features*: thermal insulation [1] resistant to external attack/durability [4, 5, 6, 7, 24, 26], autogenous shrinkage [14], refractoriness [16, 20, 21]; to the *particular technological processes*: solidification of hazardous waste [2], recycling [3,18] material modification [8, 9, 19, 22, 24], reuse of waste products [15]; as well as to some *peculiar phenomena*: self-compacting [10], self-cleaning [12], phase-change [11], adhesion [17].

The selected studies are directly addressed to the impressive objects like *nuclear shielding concrete* [21, 36, 38] and *bridge pylon* [50],and dams [51]. Some of papers has brought lecture from the past e.g. *55 years old water tower* [52] and to some extend paradoxically from *unfinished Żarnowiec Nuclear Power Plant* [53]. It is impossible to resist temptation and not notice, that T. Zdeb used the opportunity of the MATBUD to disclose his way to overcome new milestone (Fig. 7) on the concrete life curve [42].

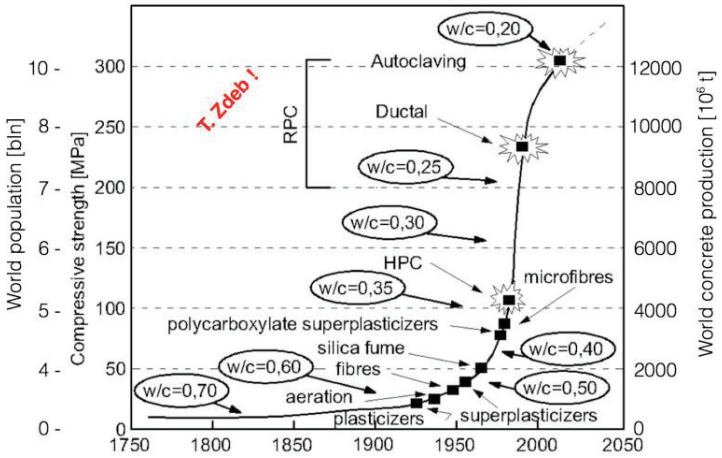

Fig. 7. The universal concrete life curve [7] with marked T. Zdeb [42] milestone achievement.

5. What is missing? What MATBUD will look like in the future?

It should be concluded that the MATBUD's paper touched in some way lots of the topics representative for research mainstream in Civil Engineering; some of them e.g. adhesion, synergy, nanotechnology in rather subtle way. Particularly, the lack of fundamental study on synergy – the lack of synergy theory should be noticed. After all synergy is the main attribute of composite materials (included concrete!). It is a part of definition: Composite is any solid polyphase material with properties that are not attainable by the simple sum of its constituent phases (synergy!) Perhaps, the paper by E. Jankowska – Renkas [54] is close to this issue, even she did not used synergy category. Certainly, the question arise – how representatives is the MATBUD for the Building Material Engineering domain if we compare worldwide efforts. While using the Microsoft Academic Search Machine, which has indexed 38 million publications and 18 million authors, it could be emphasized that in Building Material area until 2009 the number of publications exceeded number of citations (Fig. 8). This is opposite to the expected situation. It means that externally we are not attractive enough to the readers. We need more visualization and this is the also role of the MATBUD.

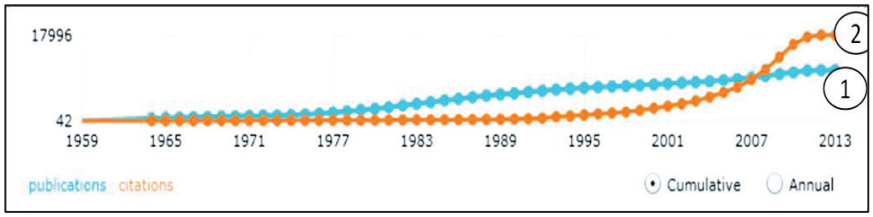

Fig 8. Cumulative number of publications (1) and citations (2) on building materials vs. Timeline (source: Microsoft Academic Search).

Many of the formerly mentioned driving forces (Chapter 3) are valid for today and simultaneously are extended timeless e.g. idea, application, performance, sustainability, demand for innovation. However, advances in information technology (IT) continue to offer new solutions to the construction industry, improving process, enabling automation and effective decision making mechanism and changing current ways of working. Around year 2030 new additional driver is expected, it will be the Knowledge Driven Sustainable Construction [37]. On the MATBUD 2015 the trailer of that did not come into sight.

Science standing alone contributes nothing to the welfare of mankind; it is not the case of the Civil Engineering. The equilibrium between Science (Applied Science) and Engineering seems to be message for future MATBUD. The question upon Performance of Sustainable Building Materials seems to be emerging leading idea: Did the research equip the Engineer with reliable tools and guidance to perform condition evaluation, establish the diagnosis and come up with realistic project objectives? Lot of question is still open and should be addressed to the further MATBUD.

6. Instead of conclusions

Science is a tribute to what we know (although we are capable of making mistakes). In the paper we have tried to analyze how the MATBUD has paid this tribute to Civil Engineering discipline. We wish to all of us – readers and Conference attendance: inspirations and creativity at the MATBUD 2015 and hopefully further ones.

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