



Proceedings
PRO 121



Syner '18 Crete

24-26 October 2018, Funchal, Portugal

Interdisciplinary Approaches for Cement-based Materials and Structural Concrete: Synergizing Expertise and Bridging Scales of Space and Time

Final Conference of COST Action TU1404

Electronic Version of Proceedings: Volume 1&2

Edited by Miguel Azenha, Dirk Schlicke, Farid Benboudjema,
Agnieszka Jędrzejewska

**SynerCrete'18: Interdisciplinary
Approaches for Cement-based Materials
and Structural Concrete:
Synergizing Expertise and Bridging
Scales of Space and Time
Vol. 1 & 2**

This is an electronic version of the proceedings of SynerCrete'18. It keeps the same page numbering of the two printed volumes, whereas the blank pages in the printed volumes are omitted.

Published by RILEM Publications S.A.R.L.
4 avenue du Recteur Poincaré 75016 Paris - France
Tel : + 33 1 42 24 64 46 Fax : + 33 9 70 29 51 20
<http://www.rilem.net> E-mail: dg@rilem.net
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ISBN Vol. 1:978-2-35158-211-4 ISBN Vol. 2: 978-2-35158-212-1
ISBN Vol. 1&2: 978-2-35158-202-2 e-ISBN Vol. 1&2: 978-2-35158-203-9
DOI: 10.5281/zenodo.1405563
Printed by Canto Redondo / VASP DPS <http://www.cantoredondo.eu>
Cover design by: Boutik Studio <http://boutik.pt/>

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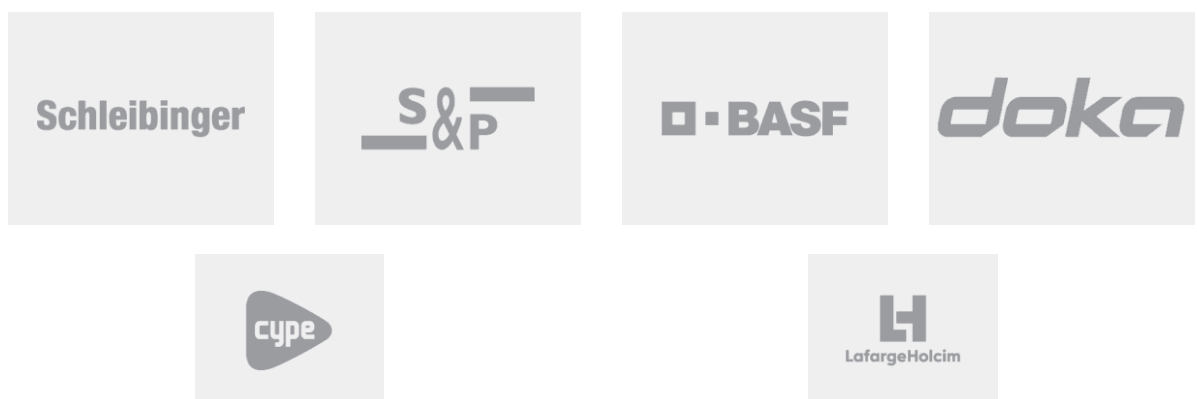
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Preface

The focus of the conference is set to communicating, discussing and arousing progress in research, development and application of Cement-based Materials and Structural Concrete, which have been attained through combination of expertise from distinct fields of knowledge. Indeed, in the words of Federico Capasso, a renowned Physicist who was one of the inventors of the quantum cascade laser:

“... we must not think of science in a disciplinary way, by making boxes. Nature does not know what physics, chemistry or biology is! It is a question of putting an end to the positivist philosophy of Auguste Comte, fortunately in decline of speed, which classified the disciplines and despised the experimental activity.”

The intent of this conference was therefore to provide added value through collaboration and by bringing together researchers and practitioners with similar views in regard to interdisciplinary approaches in the fields of Cement-based Materials and Structural Concrete: it is about **Synergizing** expertise on the ultimate goal of Structural Conc**Crete**, hence the acronym **SynerCrete**, was chosen for the conference. Exciting fields of research such as performance-based design, 3D modelling for analysis/design, Building Information Modelling and even robotics (e.g. digital fabrication or robotics design) were included, while retaining focus on multi-scale approaches at time and spatial levels.

SynerCrete'18 also marks the end of COST Action TU1404 “Towards the next generation of standards for service life of cement-based materials and structures” (www.tu1404.eu), offering a final forum to the discussions raised during the funded period of the Action, that started 4 years ago in 2014. The conference is an opportunity for the 304 COST Action members to deepen their collaboration and to focus on activities that allow the continuation of the networking which was established by the Action. A sense of accomplishment is felt by all the members of the Action, in the view of the important achievements of networking tools that were brought about by the extended Round Robin Testing Programme (RRT+), the Numerical Benchmarking Activities and 24 Short Term Scientific Missions (STSMs). Indeed, a remarkable number of papers that have been published in the two volumes of these Conference Proceedings are directly a result of one of the aforementioned networking tools.

The conference has consisted of 8 key-note speakers and 180 regular papers presented over 3 days. It is also relevant to emphasize the collaboration of another COST Action in SynerCrete: COST Action CA15202 “Self-healing As preventive Repair of CONcrete Structures – SARCOS”, which has an important contribution to the purposes of COST TU1404.

A further remark in regard to the wide international institutional support that this conference attained, is about the direct support of RILEM, fib, JCI and ACI. Specifically, with regard to the Japanese Concrete Institute, a mention is given to the special session dedicated to the most recent version of “JCI Guidelines for Control of Cracking of Mass Concrete”, as it was indeed one of the most inspiring documents that influenced the genesis of COST Action TU1404.

A final word is given in regard to the location of the conference which combines implicit symbolisms. Firstly, this is the only event of COST Action TU1404 taking place in Portugal, which is the home country of the Grant Holder and Chairman of the Action. Secondly, the conference venue is the island of Madeira, therefore not in mainland Portugal, putting attention to one of the remotest regions of Europe, officially classified as one of the eight ultra-peripheral regions of the European Union.

Miguel Azenha Dirk Schlicke Farid Benboudjema Agnieszka Jędrzejewska

October 2018, Funchal, Portugal

Acknowledgements

This publication is based upon work from COST Action TU1404 ‘Towards the next generation of standards for service life of cement-based materials and structures’, supported by COST (European Cooperation in Science and Technology).

COST (European Cooperation in Science and Technology) is a pan-European intergovernmental framework. Its mission is to enable break-through scientific and technological developments leading to new concepts and products and thereby contribute to strengthening Europe’s research and innovation capacities. It allows researchers, engineers and scholars to jointly develop their own ideas and take new initiatives across all fields of science and technology, while promoting multi- and interdisciplinary approaches. COST aims at fostering a better integration of less research intensive countries to the knowledge hubs of the European Research Area. The COST Association, an International not-for-profit Association under Belgian Law, integrates all management, governing and administrative functions necessary for the operation of the framework. The COST Association has currently 37 Member Countries.



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GAMMA AND X RADIATION ABSORPTION CHARACTERISTICS OF SPECIALLY SELECTED TYPES OF CONCRETE

Srboljub Stankovic ⁽¹⁾, Ksenija Jankovic ⁽²⁾

(1) Institute of nuclear sciences VINCA, Belgrade, Serbia

(2) IMS Institute, Belgrade, Serbia

Abstract

Medical institutions with linear accelerators, cyclotrons as installations for particles acceleration, nuclear facilities as nuclear power stations and nuclear research reactors using concrete in building construction. In cost-benefit analysis the question is what are the radiation characteristics of different types of concrete, which could be used to protect against gamma and X rays. In this paper, computer code XCOM was used for the calculation of the total mass attenuation coefficients, which is an important factor for determination of the photon attenuation, as well as during research and testing of radiation protection properties for concrete with components of different type materials. Thereby, the basic absorption radiation characteristics of ordinary and barite concretes, as well as specially selected type of concrete with magnetite and steel and concrete UHPC with barite and nanosilica as specific material composition, were considered. The results of this research point to the conclusion that before the concrete production of certain mechanical properties is approached, it is reasonable to apply the appropriate methodology with the numerical calculation of the basic absorption characteristic of the concrete for protection against gamma and X radiation.

1. Introduction

Medical institutions with linear accelerators, cyclotrons as installations for particles acceleration, nuclear facilities as nuclear power stations and nuclear research reactors using concrete in building construction. Barite aggregate is used to produce heavyweight concrete which application concerns radiation shielding in hospitals and nuclear facilities. The basic characteristics of ordinary concrete and heavy-weight concrete with barite were studied for the case of their use for shielding from gamma radiation [1, 5, 6]. In cost-benefit analysis the question is what are the radiation characteristics of different types of concrete, which could be

used to protect against gamma and X rays [2, 3, 4]. The energy deposited the transmission factor and the mass attenuation coefficients in ordinary and barite concretes have been calculated with the photon transport Monte Carlo software. The numerical simulations results show that using barite as an aggregate in the concrete is one of the solutions for gamma ray shielding. Thereat, it is shown non-destructive method for determining the gamma radiation absorption characteristics of concrete [9]. In references [10, 11], one of the goals is to implement appropriate numerical calculations for obtaining the value of the total mass attenuation coefficient in the energy range 10 keV - 150 MeV of gamma and X radiation, and their dependence in the content of barite and nano-silica in UHPC concrete with specially defined mechanical properties. Nanosilica has a dominant influence on the improvement of the mechanical properties, and barite has a dominant influence on the characteristics that increase the absorption of ionizing radiation, i.e., improves the characteristics for protection against ionizing radiation. Investigations in these references [10, 11] is designed to, by simultaneously using different portions of the two materials, nano-silica and barite, in the composition of various types of concrete conduct tests on the ability to improve the mechanical properties and properties for the radiation protection of concrete.

In this paper, computer code XCOM [8] was used for the calculation of the total mass attenuation coefficients $(\mu/\rho)_{tot}$, which is an important factor for determination of the photon attenuation, as well as during research and testing of radiation protection properties [1-6] for different content of aggregates in concrete. Computer code XCOM operates on a method of combining the values of the existing database for effective cross section of physical processes accompanying the transport of photons through different materials. This means that there is a possibility to use data bases for coherent and incoherent scattering, photoelectric absorption, and pair production cross-sections for the different chemical structure of materials which enter into the composition of the concrete.

2. Numerical methods

One of the most important characteristics of the concrete for protection against gamma and X radiation is its Total Mass Attenuation Coefficient $(\mu/\rho)_{tot}$.

Basic relations for engineering calculations the attenuation of exposure dose rate of ionizing radiation, which passes through the wall of concrete, can be displayed as:

$$X = X_0 \cdot \exp \left[- \left(\frac{\mu}{\rho} \right)_{tot} \cdot \rho d \right] \quad (1)$$

where X (C/kg s) and X_0 are intensity exposure rates behind and in front of the wall, where the wall thickness is d (m) and the density is ρ (kg/m³). This Eq. (1) is consistent with the application of Bouguer-Lambert-Beer law for attenuation of the intensity of mono energetic photon radiation for the cases of penetration of the narrow beam of radiation through a concrete wall as a protective barrier.

The definition of Total Mass Attenuation Coefficient for mixture or compound is given by:

$$\left(\frac{\mu}{\rho}\right)_{tot} = \sum_j w_j \cdot \left(\frac{\mu}{\rho}\right)_j \quad (2)$$

where w_j and $(\mu/\rho)_j$ are the weight fraction and mass attenuation coefficient of the constituent element j .

The numerical calculations included two steps: 1. For each type of concrete from Tab. 1 its composition was determined in accordance with the nomenclature of chemical elements and chemical compounds, 2. Interactive use of the program XCOM [8], where the known composition of individual types of concrete determines the total mass attenuation coefficient depending on the change of energy photon radiation.

XCOM program enables to calculate interaction coefficients for the following processes: Compton (incoherent) and Rayleigh (coherent) scattering, photoelectric absorption, and pair production in the field of the atomic nucleus and in the field of the atomic electrons. The mean free paths between scatterings, between photo-electric absorption events, or between pair production events are the reciprocals of partial interaction coefficients. The total attenuation coefficient is equal to the sum of the interaction coefficients for the individual processes.

3. Results and discussion

In our work, computer code XCOM was used for the calculation of the total mass attenuation coefficients for four different concrete types, which is specified in Table 1.

Table 1: Types of concrete for numerical calculations of the total mass attenuation coefficients with software code XCOM [8].

Mark	Type of concrete	Density (g cm ⁻³)	Material composition data in [reference]
CB	Concrete, Barite (Type BA)	3.350	[7]
CMS	Concrete, Magnetite and Steel	4.640	[7]
COR	Concrete, Ordinary (NBS 04)	2.350	[7]
B5n	Concrete, UHPC barite nanosilica 5%	2.830	[11]

The dependence of values total mass attenuation coefficients on energy photon radiation is shown in the figure Fig. 1.

On the graphs Fig. 1, one can see, that total mass attenuation coefficients $(\mu/\rho)_{tot}$ has dependence of the photon energy (E): a) in three ranges for concrete types CMS and COR,

decreasing sharply at low energies ($E < 0.15$ MeV), decreasing slightly in the middle range ($0.15 \text{ MeV} < E < 6 \text{ MeV}$) and increasing slightly at high energies ($E > 6 \text{ MeV}$); b) in three ranges for concrete types CB and B5n, decreasing sharply in bottom range ($10 \text{ keV} < E < 400 \text{ keV}$) with the sharp discontinuity around 30 keV, decreasing slightly in the middle range ($0.4 \text{ MeV} < E < 6 \text{ MeV}$) and increasing slightly at high energies ($E > 6 \text{ MeV}$); c) in the energy range of 400 keV to 6 MeV values for the total mass attenuation coefficients are approximately the same for four different types of concrete. The results, which we have pointed out, are tied to different photon absorption mechanism for different energy range. The sharp discontinuities in energy dependence for total mass absorption coefficient are connected with the processes of the photoelectric absorption.

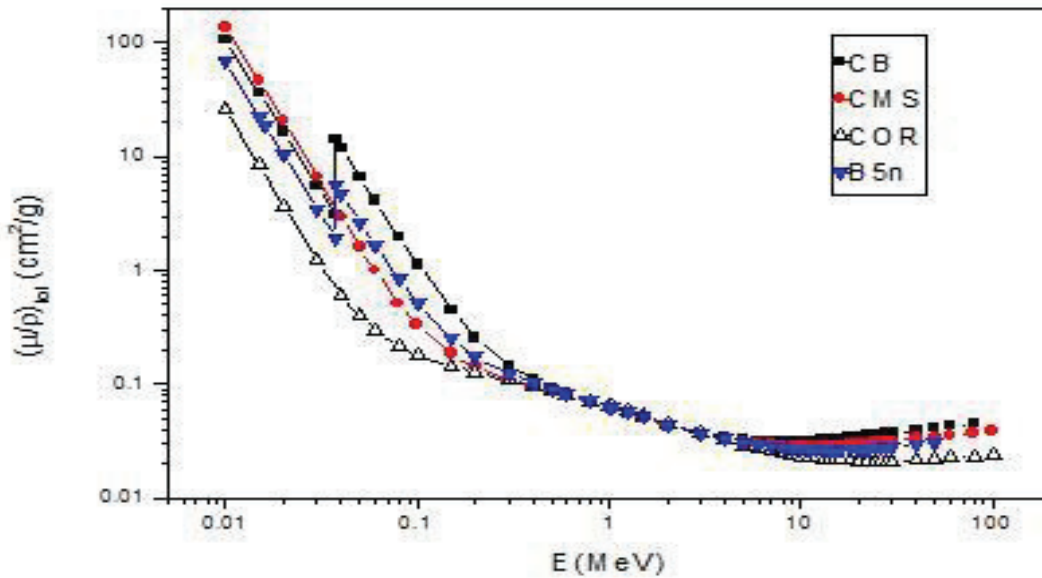


Figure 1: Total mass attenuation coefficients for four different concrete types.

4. Conclusion

In this investigation, based on the results of the corresponding graphs for Total Mass Attenuation Coefficient $(\mu/\rho)_{tot}$ it can be concluded that in the range of energy of gamma and X radiation from 30 keV to 300 keV, concrete types CB and B5n with barite sand has greater protective power than concrete types CMS or COR. Concrete type CMS with magnetite and steel has greater protective power than other three concrete types for the energy of gamma and X radiation $E < 30 \text{ keV}$, while the concrete type CB is with better characteristics than other types of concrete for the attenuation of the radiation beam for photon energies greater than 30 keV. The results of this research point to the conclusion that before the concrete production of certain mechanical properties is approached, it is reasonable to apply the appropriate

methodology with the numerical calculation of the basic absorption characteristic of the concrete for protection against gamma and X radiation.

Acknowledgements

The work presented in this paper is a part of the investigation conducted within the research projects TR 36017 and III 43009 supported by the Ministry of Education, Science and Technological Development, Republic of Serbia. This support is gratefully acknowledged.

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