Comparative analysis of magnesium oxide boards properties

D Mokrenko1 and M Kozlovská1

1 Technical University of Kosice, Faculty of Civil Engineering, Institute of Construction Technology, Economic and Management, Vysokoskolska 4, 042 00 Kosice, Slovakia

Abstract. The current sustainability trends pose high demands on building materials and products. Those with potential to be labelled as an environmentally-friendly product or technology are getting preferred. One of the natural resources with such potential is magnesite, whose resources are widely found in Slovakia. The article deals with analysis of the magnesium oxide board properties as the most popular MgO-based building product. The comparative analysis of magnesium oxide boards with other available building boards (plasterboards, oriented strand boards) is included in the article and especially from the point of magnesium oxide boards’ benefits.

1. Introduction
Currently, buildings account for around 40% of greenhouse gas emissions, with the USA, China and Russia contributing the most [1]. As a result, building ecology is becoming one of the main aspects that can influence the solution of the global climate protection problem and contribute to the sustainable development of the planet as a whole [2]. Most of the research focuses on issues of environmentally sustainable architecture and urbanism, integrated territorial development, the use of energy-efficient equipment, reducing heat loss in buildings and the like. There is less research on the development of environmental building materials and the term ‘eco-material’ is more of an advertising and marketing meaning. Ecological construction cannot be built without the use of environmentally-friendly materials and products that have a low carbon footprint, emission of hazardous substances, increased biological stability and other properties.

The ideal material for research is magnesium oxide board due to the following factors. It is a 100% environmentally friendly material that can replace almost all available building boards such as plasterboard, cement board, OSB board or plywood [4]; Slovakia is the 6th in MgO mining in the world [3]; MgO is part of various natural building materials that have been used for antiquity and have passed the test of time [5]. What makes a magnesium oxide board different from others is its fire grading, acoustic and heat insulation ability, water and damp resistance, the ability to reflect IR (infrared) rays, elasticity and strength, resistance to pests, fungi, rot, rodents, antiallergic and ecological [4]. Thanks to its properties, the magnesium oxide board is absolutely safe for health and makes the building environment safe and healthy inside. Based on the theoretical analysis and synthesis of acquired knowledge, the aim was to compare the properties of magnesium oxide board with similar plasterboard, cement board, OSB or plywood boards and to give it strengths over others.

2. Description of the present state
Magnesium oxide (burnt magnesium) is produced by the thermal decomposition of magnesium carbonate MgCO3 [8]. High melting points as well as chemical inertness and thermal stability determine the preferred use of magnesia in the manufacture of refractory materials used in the high temperature processes of steel, cement, lime, glass and non-ferrous metals [9].

The world’s largest consumer of magnesium is the refractory industry. The metallurgical industry needed high-quality refractory materials that can withstand molten metal. The magnesite has become one of such refractory natural materials because its main quality parameter is high heat resistance. Other
sectors - agriculture, chemical, ceramic, construction, pyrotechnic, environmental [10] have their own requirements for specific properties of magnesium utilization.

Figure 1. Examples of magnesium-based products across different industries.

Products for the metallurgical and ceramic industry consist of dead-burned magnesite clinkers, which are intended for the production of monolithic materials, products intended for the preparation of new soils, protection of linings of steel aggregates. Products used in the chemical industry are intended for the production of magnesium-based chemicals [11]; the product CCM 78 acts as a binder, the number 78 indicates how much of the magnesium oxide is in the powder [12]. CCM 85 is intended for use in the agricultural industry as a mineral additive for animals, which has a positive effect on their health due to the high magnesium content. In addition, it can be used for the production of fertilizers in the chemical industry, or for eliminating the effects of acid rain [11]. In the construction industry, magnesium is used to the production of building materials and components.

Magnesium oxide board (MgO board) is a large format construction board, generally in white color (Fir.2). MgO board is making from environmentally friendly natural material that is safe for health and does not release toxic substances when used. Important features of the magnesite board are that it is fire resistance, elastic and solid, frost-resistant, waterproof, ecological, antiallergic, heat-reflective, healthy, resistant to mold and rodent [7]. A unique feature of the magnesium oxide board is that the board actively consumes CO₂ from the air throughout its life cycle, thereby continuously cleaning it and improving the quality of the indoor environment [4]. The magnesium plate can be used practically everywhere. This product is used for ceilings, partitions, fireplaces, all types of interior and exterior wall cladding, ventilated facades, creative ceilings and wherever a building needs to be protected from fire, rot and mold. They can be easily tiled, plastered or painted.

According to the market analysis of MgO boards for years 2018-2023 [19] the global MgO board market is segmented into five major regions, namely, North America (U.S., Canada), Europe (U.K., France, Germany, Russia), Asia-Pacific (China, Japan, Australia), South America (Brazil, Argentina), and Middle East & Africa (South Africa, Saudi Arabia). There are many producers and even more suppliers in these regions. Each producer of MgO boards has its own recipe for his product, which results in some different properties. In general, magnesium oxide board is made up of "Sorel cement" - a mixture of magnesium oxide, provided with additional elements. Zhangjiagang Oriental Construction Material Co., Ltd. states [21], that magnesium oxide board is made of high purity magnesium oxide, MGO sulfate (MgSO₄), replace of magnesium chloride (MgCl₂), high strength fiber glass mesh, perlite, non-woven fabrics. According to North American MgO LLC [20] MgO board consists of 67% MgO, 18% SiO, 5% Fly Ash Filler, 9% additives and 1% Fiberglass gauze. Exclusive importer of MgO boards in Slovakia shows again a different structure of boards [6]: 50% MgO, 25% MgCl, 15% Cement-based sealants, 8% SiO, 1% Fiberglass gauze, 1% other.
From the study of several sources such as Product Catalog by MGO Slovakia [4], Magnesium Oxide by G Swanson [7] and Technical data sheet by RETRAST TRADE [13] it is possible to consider the strengths and weaknesses of MgO boards (table 1).

Table 1. Strengths and weaknesses of MgO boards.

| Strengths                  |                  |
|----------------------------|------------------|
| Fire resistance            | The material is resistant to temperatures of 800 °C and can withstand the effects of an open flame for up to 240 minutes when it is part of prefabricated structures. |
| Resistant to moisture      | It does not deform, softens and rot under the influence of moisture or steam. |
| Frost resistance           | The material can withstand more than 50 freeze-thaw cycles, which does not destroy it. |
| Strength                   | It has good impact resistance and increased strength. Material resistant to impacts greater than 5 KJ/m². The flexural strength is from 15 MPa to 22 MPa. |
| Soundproofing              | The material has good sound absorption and provides high sound insulation. Noise protection board 8 mm - 29 dB. |
| Thermal insulation         | It has low thermal conductivity properties - the thermal conductivity coefficient is 0.216 W/mK. |
| Constant dimensional stability | It is not affected by moisture, heat or cold. |
| Thermal accumulated effect | This is a newly revealed property of the magnesite board, which is 50% higher for plasterboard. |

| Weaknesses                 |                  |
|----------------------------|------------------|
| Price                      | In today’s building materials market, the price for this product is more expensive when compared to similar materials. |
| Demand                     | Demand for these materials is relatively low due to competition in the market cheaper materials and lack of consumer knowledge. |
| Availability               | Relatively few countries are involved in MgO mining due to a lack of awareness of its properties. |
| Quality                    | Occurrence of defects due to not always correct material composition. |

This comparison shows that MgO boards have more strengths than weaknesses and give the possibility to recognize that magnesium board has great potential in the construction market as such. Approximately, since 2012 MgO boards have used more intensively also in Slovakia. The exclusive importer is MGO Slovakia s.r.o., which sold it on the market under the name SUPERDOSKA. Importers themselves declare that there is no uniform recipe for the production of MgO boards and boards of individual producers differ significantly in their properties. In short, what applies to one board may not apply to another manufacturer’s boards at all. From the references of many who used MgO boards in construction in Slovakia, the biggest discussed problem was the moisture of boards used in exteriors. Paradoxically, moisture resistance is reported as one of the benefits of MgO boards. There are two possible ways of explaining this “quality”. Some manufacturers in the material composition do not
adequately apply the necessary additives, or on the other hand, users do not apply all the technological procedures for the use of MgO boards outdoors – especially in terms of their subsequent surface treatment.

Despite the fact, the biggest barrier in the expansion of the use of MgO boards appears to be their price. Further comparisons should show whether the disadvantage in terms of price has its justification in relation to better material and construction parameters of MgO boards compared to other built boards.

3. Materials and methodology
To compare the parameters, building boards on different material bases were chosen, which are most often used for dry construction in Slovakia (table 2). The most used are plasterboards, produced on the basis of plaster. Plasterboard is a panel made of calcium sulfate dehydrate (gypsum), with or without additives, typically extruded between thick sheets of facer and backer paper. The most commonly used wood-based boards are OSB and Plywood. OSB (Oriented strand board) is a type of engineered wood similar to particle board, formed by adding adhesives and then compressing layers of wood strands (flakes) in specific orientations. Plywood is a material manufactured from thin layers or “plies” of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another. These boards are traditional and long-used building boards (for example OSB board was invented by Armin Elmendorf in California in 1963). From modern innovative board was chosen board Cetris. Cetris is a cement-bonded particleboard with smooth naturally cement-grey surface. In order to make the parameters more objectively comparable, boards were selected with the same thickness of 12 mm.

Table 2. Selected products for comparison of building board parameters.

| Material base          | Product                                      | Producer/Supplier                  |
|------------------------|----------------------------------------------|------------------------------------|
| Magnesium              | SUPERdoska Basic (MgO board), 12x1220x2440mm | MGO SLOVAKIA s.r.o.                |
| Cement bonded particle| CETRIS-BASIC, 12x1250x3350mm                 | Bauintegra, s.r.o.                 |
| Gypsum                 | Plasterboard RB (A), 12x1200x2500mm          | Saint-Gobain Construction Products, s.r.o. |
| Wood veneer            | Plywood joinery Beech/Spruce B/CP, 12x1250x2500mm | JAF HOLZ Slovakia spol. s.r.o.     |
| Wood fiber             | OSB 3 4P+D uncut Kronospan, 12x625x2500mm     | JAF HOLZ Slovakia spol. s.r.o.     |

Based on available data from technical literature, data sheet and catalogs of MGO Slovakia [4], Retrast Trade [13], OBI [14], Relend [15], GOST 3916.1-96 [16], STN 73 0862 [18] and Cetris [17] for comparison were selected following parameters:
- market prices per 1 m²;
- mass weight – the higher density makes material stronger and more resistant to change its shape;
- elastic modulus – the more flexible the material, for example, allows to create curves in the construction design;
- thermal resistance – the higher the thermal resistance of the less heat is lost through the construction;
- acoustic resistance – the higher the value, the more resistant the material is to the sound transmission;
- beam strength, tensile strength, compressive strength, impact strength - the higher the value, the more durable the material;
- content of formaldehyde – the lower the formaldehyde content, the healthier the material;
- fire reaction class - ranging from the best class (A - nonflammable) to the worst class (C – flammable);
- resistant to moisture – possibility to use in the wet environment;
- mold and pest resistance – contributes to a healthier indoor environment.

4. Results
Data on individual boards found from the above sources were processed into a table 3. A gray background highlights the best result in a given property.
The aim of the paper was to prove that a more modern and innovative building board is a better solution in terms of mechanical and environmental parameters. The results confirmed that the price of traditional boards is about 50% higher than for innovative boards, on the other hand, all properties showed worse parameters (except for compressive strength wood-based boards - whose value was comparable). Additional finding points to the fact that, from the perspective of modern innovative boards, the price of MgO board is even lower than that of Cetris, with the MgO board showing significantly better values in six parameters (beam, tensile and compressive strength, weight, thermal resistance, and formaldehyde). In conclusion, the higher price of MgO board is clearly justified, as it shows significantly better properties.

Table 3. Comparative analysis of MgO board, Cetris, Plasterboard, Plywood and OSB board properties.

| Properties                 | MgO board | Cetris | Plasterboard | Plywood | OSB board |
|----------------------------|-----------|--------|--------------|---------|----------|
| Market price [EUR/m²]      | 9.28      | 9.5    | 4.05         | 5.49    | 4.68     |
| Mass weight [kg/m3]        | 1000      | 1350   | 680          | 600     | 620      |
| Elastic modul [MPa]        | 6045      | 6800   | 2200         | 3500    | 3500     |
| Beam strength [MPa]        | 18        | 11.5   | 2.2          | 16      | 16       |
| Tensile strength [MPa]     | 11        | 0.63   | 1.8-2.5      | 0.3     | 0.3      |
| Compressive strength [MPa] | 18        | 15     | 6.8          | 28      | 20       |
| Impact strength [kg/m²]    | 5         | 3.6    | 3.4          | 0       | -        |
| Thermal resistance [m²K/W] | 1.14      | 0,037  | 0,1042       | 0,12    | 0,12     |
| Acoustic resistance [dB]   | 48        | 30     | 25           | 23      | 25       |
| Content of formaldehyde [g/100g] | 0       | 0      | 0            | max.8   | max.8    |
| Fire reaction class        | A1        | A2     | A2           | C2      | C1       |
| Resistant to moisture      | Yes       | Yes    | No           | No      | No       |
| Mold and pest resistance   | Yes       | Yes    | No           | No      | No       |

* producers have not included this value in the product catalog;  
- gray color means a better result.

In terms of prices follows that MgO board has a comparable (even lower) price than a board Cetris. Prices of these two modern boards (MgO board, Cetris) are about 50% higher than the prices of drywall or wood-based boards. The significant difference between boards that are “more expensive” and “cheaper” boards is in almost twice value of mass weight. Further more or less different strength parameters are deriving from this parameter. In terms of the modulus of elasticity, the values of MgO board and Cetris board are comparable, but in other strength parameters the MgO board appears to be better. Higher than all boards, MgO board has beam strength, significantly better is tensile strength and impact strength. In terms of compressive strength, it has somewhat lower values than wood-based panels, but better than Cetris and of course plasterboard. The MgO board has a nearly twice as better parameter as all other boards in terms of acoustic resistance, and even more significant are differences in thermal resistance. The MgO board also shows the best values in fire reaction, while of course the worst reaction to fire is wood-based boards. In terms of health safety, the worst are wood-based boards again, since they are glued and contain a small (although allowed) amount of formaldehyde. Only MgO board and Cetris board have resistance to moisture and mold and pest resistance. Wood-based boards and plasterboard do not have these properties.

It follows that the higher price of MgO board is clearly justified, as it shows significantly better values in almost all parameters. The Cetris board, which has even higher price, although only some of the parameters have comparable values to the MgO board.

5. Conclusion

Building boards are an integral part of all buildings. They have a wide range of applications (walls, partitions, floors, roofs, soffits) as well as a relatively broad material base (gypsum, wood fiber, particle, plywood, fiber cement). The paper analyzed the properties of a relatively new - innovative building board, made on a magnesium base. Many sources list a number of their benefits that improve the performance of traditional gypsum and wood-based building boards (fire, mold and pest, acoustic or thermal resistance, strength parameters - especially tensile and impact strength, health safety, resistant to moisture, mass weight and elastic modul). On the other hand, it appears that their wider use is hindered by a price that is higher than traditional building boards. The aim of the paper was to prove that a relatively higher price is justified in relation to better properties. For comparison were selected three traditional gypsum or wood-based boards and one modern board - based on cement bonded particle. In relation to the price were examined 12 physic-mechanical and environmental parameters. The results confirmed that the price of traditional boards is about 50% lower than for innovative boards, on the other hand, all properties showed worse parameters, some even more than 50% (except for compressive strength wood-based boards - whose value was comparable). Another finding points to the fact that, from the perspective of modern innovative boards, the price of MgO board is even lower than that of Cetris, with the MgO board showing significantly better values in six parameters (beam, tensile and compressive strength, weight, thermal resistance, and formaldehyde).
compressive strength; thermal, acoustic and fire resistance). Based on the results, it can be concluded that MgO boards have an unambiguous justification and potential for their wider use, both in terms of price and in terms of their better parameters.

6. References
[1] World Business Council for Sustainable Development 2009 Building Energy Efficiency: Market Transformation

[2] Benuzh A and Kolchigin M 2012 Analysis of the concept of green construction as a mechanism for ensuring the environmental safety of construction activities

[3] Komelin I and Lysenko A 2019 Interaction of magnesium production salt melts with atmospheric air. Izvestiya Vuzov. Tsvetnaya Metallurgiya

[4] MGO Slovakia s.r.o. 2011 Product Catalog 2011

[5] Voroncov V and other 2008 Natural materials in architecture: training aid

[6] STEELSOFT s.r.o. 2012 Safety data sheet

[7] Swanson G 2010 Magnesium Oxide, Magnesium Chloride and Phosphate-based Cements

[8] Durisin J and other 2004 Chemistry I examples and tasks

[9] Knunanc I and other 1990 Chemical Encyclopedia. Volume 2

[10] Shipcov V 2011 Magnesian RAW: history, world capacity and resources of Karelia

[11] SMZ, a.s. Jelsava 2015 CCM 85

[12] Selmo 2018 Periclase powder PPE-88

[13] RETRAST TRADE, s.r.o. 2012 Technical data sheet

[14] OBI [Online] Available at: http://www.obi.sk/

[15] STN 73 0862 Determination of flammability degree of building materials

[16] North American MgO LLC 2018 MagTech Ultra Magnesium Oxide Board - Environmental Product Declaration

[17] Zhangjiagang Oriental Construction Material Co., Ltd. Innovative home building system OCM boards and Housing Panel

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