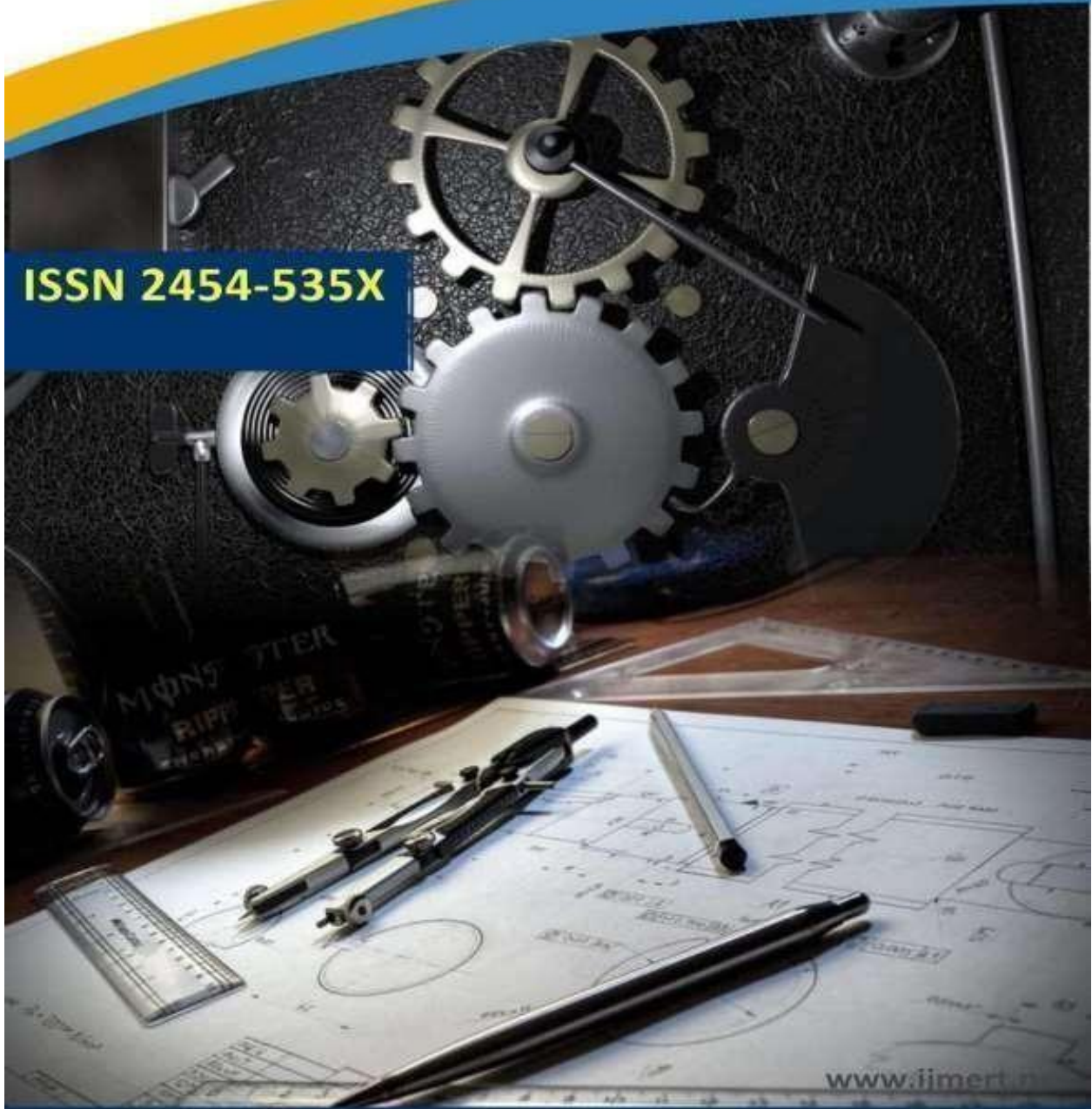




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Studies on the Mechanical Properties and Chemical Reactivity of Hydrophobized Lightweight Aggregate Concrete with the Incorporation of Sewage Sludge

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ABSTRACT

Weakened by sewage sludge, the lightweight aggregate-concrete in this article is a combination of sludge from municipal sewage treatment plants and lightweight aggregates. Laboratory tests of material physical properties are discussed in this article. Admixing reactive polysiloxanes water emulsion with a substance that absorbs water reduced its water absorption capacity. An indirect approach for detecting moisture in porous materials was used: Time Domain Reflectometry. Both types of lightweight aggregate-concrete had their heat conductivity coefficients measured. Light aggregates reinforced with sewage sludge were found to be suitable for the creation of future products after an analysis of their moisture and heat qualities.

Keywords: sewage sludge; lightweight-concrete; hydrophobization

1. Introduction:

Recent years have seen an increase in the modernisation of locally mined resources. To underscore the need of lowering primary energy usage, there is a rising tendency. As part of the UE 2006/32/WE3 Directive, Poland has nine years from January 1, 2008, to December 31, 2020, commencing on January 1, 2008, to reduce final energy consumption by building occupiers. Encouragement of renewable energy sources and the use of power-saving technology during construction were deemed to be the most effective ways to increase building sector energy efficiency [2].

A central heating system contributes for between 31 and 71 percent of final energy consumption in Polish homes, according to Central Statistical Office statistics from 1997–2007. This is about in line with the European average of 50 percent. So much carbon dioxide is released into the atmosphere in this way that it accounts for nearly half of all gas emissions. It's common knowledge that construction technologies have an impact on the environment, mostly via fuel use and CO₂ emissions. [5–9].

In addition to durability, The physical and moisture properties of building materials have a direct impact on air quality, thermal comfort, and energy use.[10,11]. Condensation is a common occurrence in uninsulated buildings, particularly owing to poor thermal insulation and lack of ventilation.

Ventilation in the room [12]. A 4- to 6-fold increase in porous materials' heat conductivity was validated in the literature, and this is especially crucial for partitions that contact the ground. The presence of water in masonry significantly affects interior air quality, allowing hazardous bacteria to thrive and causing biological and chemical corrosion, which increases exploitation costs. Mold and fungus may thrive in building barriers if they are exposed to high levels of moisture and temperature. As laboratory tests have shown, mould thrives under unfavourable, constantly changing moisture and temperature conditions. As the amount of moisture in the air rises, so does the risk of respiratory and skin irritations and infections.



In response to the European Union Directive 2006/32/WE3, environmentally friendly and energy-efficient building materials are becoming increasingly common [2]. Lightweight aggregate-concrete is one of the materials used in energy-saving civil engineering because of its high heat and moisture tolerances. Construction components may be lighter thanks to lightweight aggregate-concrete, which is an alternative to regular concrete. Particle density ranges from 2.4 to 3.6 for the majority of natural aggregates. Density of lightweight aggregates is between 0.8 and 2 grammes per cubic centimetre (g/cc). with a density of 2.0 g/cm³.

Because smaller foundations and structural parts like columns or walls may be used in place of larger ones, the reduction in dead weight may lower building costs. In order to make lightweight concrete, it was discovered that the use of lightweight aggregates modified with municipal sewage sludge was possible. Reusing industrial waste and reusing recycled materials in building is nothing new, but it has gained popularity in recent decades all around the globe. Some wastes may be turned into ceramics by heat treatment.

The quantity of emerging sewage sludge has increased dramatically due to an increase in the number of Sewage Treatment Plants and a decrease in carbon compounds and biogas in sewage treatment processes. Sludge that is stabilized by methane digestion typically includes heavy metals that are not hygienic safe. Sewage sludge may be hazardous to the environment in many circumstances, thus it must be appropriately treated. European Union rules and legislation prohibit the use of sludge in landfills and in agriculture. Ceramics and energy-efficient lightweight aggregate concrete blocks, for example, may both benefit from sludge as an additive. Water treatment sludge is known for its high absorption of moisture due to the tiny particle structure of the sludge. Lightweight aggregate-concrete combinations and ready-products are adversely affected by this. The materials' increased heat conductivity has the most significant impact on the heat flow process. One of the most critical aspects of lightweight concrete manufacturing is the kind and distribution of pore networks and the connections between them and the aggregate surface. When the lightweight aggregate is covered with cement mortar, volumetric density differences cause the aggregates to flow out if the cement mortar does not have a proper viscosity. Several approaches may be used to prevent the undesirable phenomena of water being drained from the hydration process by lightweight aggregate. The aggregates may be protected against self-contraction by first being wetted. Cement grout or ceramic shell may also be used to cover the aggregates, which reduces water absorption, improves the density of aggregate particles, and therefore has a significant impact on concrete strength.

Impregnation of aggregates is a novel technique that fills air spaces and prevents water penetration while ensuring that particles stick to the cement matrix continuously. Capillary water absorption is reduced by hydrophobizing aggregates and mortar, yet the pores and capillaries remain open, allowing for unrestricted passage of gases. Hydrophobizing chemicals such as siloxanes, which are water-soluble organic silica compounds, may be added to cement in concentrations ranging from 1 percent to 2 percent. Building items would no longer suffer from excessive moisture if hydrophobization was used to make lightweight blocks. As an added benefit, it would prevent salt solutions from being transported into the brickwork, which might lead to damage from freezing and defrosting, as well as crystallization of dissolved salts. Additionally, salt-containing materials have a higher moisture content than non-salt-containing ones. Heat loss occurs as a result of increased material heat conductivity caused by excessive moisture in the air. This increases the heat flow process.

Research shows that the use of a new kind of lightweight aggregates cement that contains foamed foamed sludge may be suggested for use in practice based on the results of this research. It will be possible to demonstrate the energy-saving and environmental benefits of using sewage sludge as an ecologically friendly and sustainable additive to light weight concrete blocks by measuring its heat-moisture and mechanical characteristics. Introducing innovative energy-saving materials into the construction industry increases the industry's ability to reduce final energy usage.

2. Materials and Methods



For this study, the researchers looked at three different aspects of aggregates: their composition, the raw materials utilized in their manufacturing and ultimately (and primarily) the specifications of the lightweight aggregate concretes they employ.

“Determination of the Characteristics of Raw Materials Used in the Production of Lightweight Aggregates”

Light Aggregates Company “Keramzyt” is actively exploiting the “BudyMszczonowskie” bed in Poland for the manufacturing of aggregates. The sewage sludge used in this experiment came from the “Hajdów” mechanical-biological facility in Lublin, Poland, For both municipal and industrial waste. Examination of sludge from a dewatering station mechanically For the evaluation of physical and chemical attributes, the following criteria were used: Analytical methods utilized to evaluate the chemical composition of the waste were based on Atomic Emission Spectroscopy (ICP) and ICP/MS, both using Perkin Elmer ICP/MS equipment.

We used X-ray fluorescence to figure out the chemical make-up of clay. The Almelo, Netherlands-based PW 1404 (Panalytical) spectrometer was employed in the investigation. The induction source employed a lamp with a double anode with a maximum output of around 3 kW. (Cr-Au).

An XRD approach was used to analyze the mineral composition of the samples, which comprised a PW 3050/60 goniometer, a Cu lamp, and a graphite monochromator (clay and sewage sludge). To conduct the experiment, angles of 5 to 65 were used (2 Theta). It was utilized to analyze the diffraction data using Philips Highscore software. (High Score Plus, version 4.1). Using the ICDD's PDF-2 version 2010 database, mineral phases were identified. The samples used in the XRD and XRF examinations weighed 4 g, and each measurement was made three times. XRD:

EDAX Corporation's EDS X-ray-EDS scanning electron microscope (SEM) was used by researchers to study the morphological shapes and chemical compositions of substrates to arrive at their conclusion (EDAX Inc., Mahwah, NJ, USA). Sample surfaces totaling 25 mm² were examined by SEM.

“Manufacturing of Lightweight Aggregates”

After sampling, the clay was immediately dried to a uniform mass. After that, a ball mill was used to grind it down to a particle size of 0.5 mm. Sludge from the toilet was dried and pulverised to less than a millimeter in diameter using a mortar and pestle. After grinding dried sludge to a fine powder, the combination was made in the following ratio: 10% sludge, 90% clay. For a plastic-like consistency, the ingredients were blended with the appropriate amount of water before being poured into a mixing bowl. Next, air-dry spheres of a coarse fraction of 8 to 16 mm were made and maintained in a 110°C laboratory oven for two hours to produce their final air-dry condition. In a chamber furnace, the dried samples were heated to 1150 °C for 30 minutes. The “Keramzyt” Lightweight Aggregates Company in now, Poland, provided the second kind of aggregates.

Manufacturing of Lightweight Concrete

With these ingredients, CEM I 32.5R cement, light aggregates (eight to sixteen millimetre), quartzite sand (0 to two millimetres), and municipal water supplied by the water supply system were utilised to produce the samples of concrete. Polysiloxanes, organic silica compounds that may be dissolved in water, were employed as a hydrophobic ingredient at an amount of 2% of the cement mass. Samples of the concrete were manufactured in Poland following Polish specifications. In the design, the plastic consistency D_{max} was set at 16 mm. Composition per cubic metre of the tested light concretes.

“Determination of Lightweight Concrete Properties”

The density and porosity of the samples were measured using the standard PN-EN 1936:2010—a pycnometer method, under laboratory conditions, and at a temperature of 20 °C. It took 28 days for the apparent density to be determined. Using six cuboid concrete samples, the apparent density of the material was calculated using the following formulas: The standard was used to determine the density and open porosity volume.

Researchers also looked at both materials' capillary rising capabilities. The following studies provide evidence of TDR (Time Domain Reflectometry) use. Three unique types of concrete were used in the experiments. They had been weighed and dried and were ready to be put to use in the experiments. The samples were measured as follows: This item's size is specifically listed as 150 mm. Specifically designed TDR probes were employed in the experiment, which focused on measuring moisture in hard building materials. Amounts of 5 and 10 centimetres of water were placed in each sample (Figure 1). For this experiment, we utilised a TDR multimeter made by E-Test in Lublin, Poland. For the setting we used in our test, we found that the measurement's average level of uncertainty was about volume. Over the course of 350 hours, researchers tracked changes in dielectric permittivity, which they then converted to moisture content using the same procedures detailed in the following study.

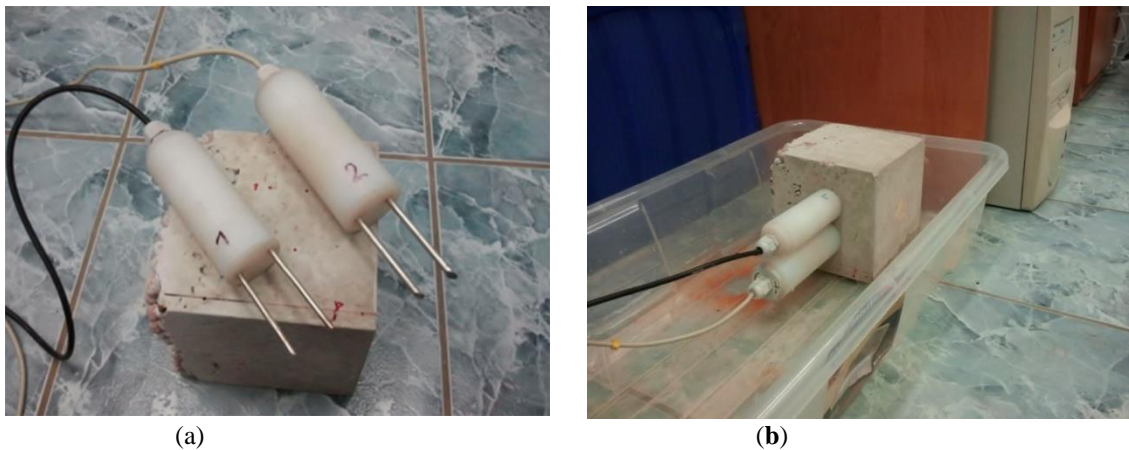


Figure 1. Determination of the capillary uptake process: (a) presentation of the sample and the modified probes; and (b) measuring setup ready for the experiment.

“Parameters of Lightweight Aggregate-Concretes”

The physical properties of the researched lightweight concretes are listed in a table. Using Time Domain Reflectometry data, the apparent permittivity fluctuations in moisture are recalculated in Figure 5.

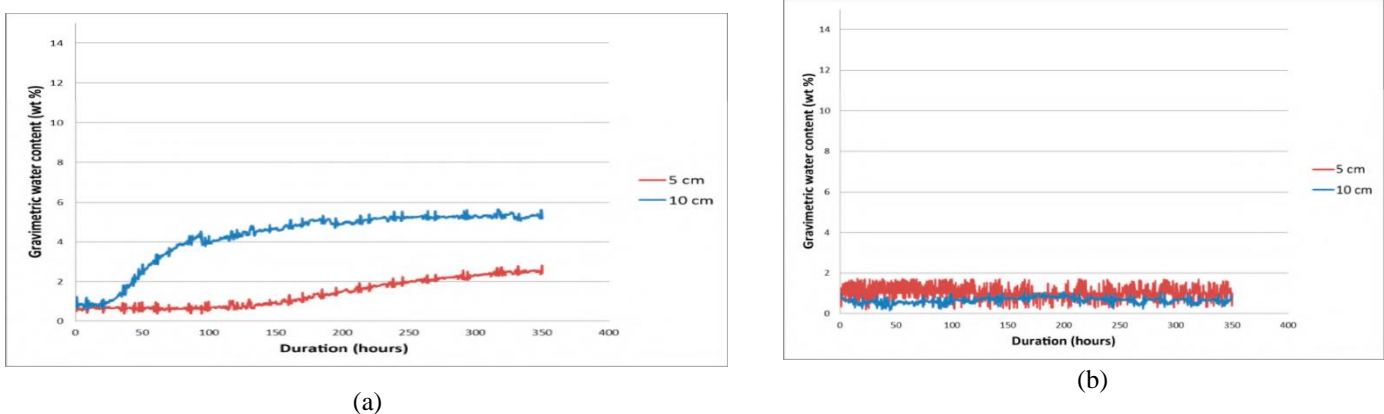


Figure 5. Capillary rise phenomenon determined in this research: (a) lightweight aggregate concrete with aggregates from now; and (b) lightweight aggregate concrete with aggregates from sewage sludge.



3. Conclusions

Concrete with a density of 1400–1960 kg/m³ may be made using lightweight aggregate-concrete that has been treated with sewage. When wastewater was used as a concrete component instead of commercially available lightweight aggregate, a 12.86 percent increase in porosity was seen overall. “SEM verifications backed up these findings as well. Light aggregates and cement mortar were shown to have a strong connection after microscopic studies of the contact locations were performed. None of the previously mentioned contact sites had scuffs, dents, or voids. As a concrete additive, hydrophobic pretreatment reduces the absorptivity of both lightweight aggregate-concrete combinations by 3–7 percent. Lightweight aggregate containing sewage sludge absorbs more fill, lowering the total absorptivity of light concrete by about 57%. TDR study fully inhibited the capillary rise process. The heat conductivity coefficient of lightweight aggregate-concrete was reduced by around 7 percent to 10 percent. Compressive strength was reduced as a consequence of the sewage sludge additions. The reduced weight capacity of lightweight aggregate-concrete blocks. Lightweight aggregates made with sewage reduced the frost resistance of the tested concretes by about 4%, although this was still within acceptable limits. Wastewater treatment plants are producing a growing amount of sewage sludge, which may be put to good use using the methods described in this article.

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