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ASSESSMENT OF USING WATER OBTAINED THROUGH EVODROP TECHNOLOGY EXPOSED TO ELECTROMAGNETIC WAVES ON CONCRETE PROPERTIES BASED ON FT-IR AND SEM ANALYSES

Ignat Ignatov[1], Fabio Huether[2], Paunka Vassileva[3], Mario T. Iliev[4], Alexander I. Ignatov[1], Chavdar Stoyanov[1]

[1] *Scientific Research Center of Medical Biophysics (SRCMB) 32 N. Kopernik St., Sofia 1111, Bulgaria*
[2] *EVODROP AG, Brüttisellen, Zürich, Switzerland*
[3] *Institute of General and Inorganic Chemistry (IGIC) Bulgarian Academy of Sciences (BAS), Acad. G. Bonchev St., Bl. 11, Sofia 1113, Bulgaria*
[4] *Faculty of Physics, Sofia University "St. Kliment Ohridski" Sofia 1000, Bulgaria*
E-mail: mbioph@abv.bg

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ABSTRACT

Various methods are applied to improve the quality of cement and concrete. Many efforts are made to enhance their quality by introducing additional compounds that can stabilize the chemical bonds between their components. Significant effects on hydrogen bonds under the influence of magnetic and electromagnetic waves have been observed. Results have been published with permanent magnetic fields for water treatment for concrete preparation with magnetic inductions B = 4000, 6000, 6000, 9000, and 9250 Gauss. Electromagnetic (e. m.) treated water has emerged as a promising approach for improving the properties of construction materials.

Our investigation concerns the properties of concrete. Concrete is a composite building material mainly consisting of cement, aggregates, water, and various chemical additives. Water was activated with electromagnetic fields from solenoid, ranging from 20 to 40 kHz. The study employs Fourier Transform Infrared (FT-IR) spectroscopy analysis and the Scanning Electron Microscope (SEM) method. The experiments were performed on samples and control samples. The control samples were obtained with water before activation with EM fields. Treating the water in concrete preparation with electromagnetic fields leads to greater mixture homogeneity. SEM images substantiate this outcome. The FT-IR peaks are linked to heightened chemical reactivity from improved water parameters attributed to the treatment with the EVOdrop device.

Keywords: electromagnetic fields, water, concrete, SEM, FT-IR.

INTRODUCTION

The quality and performance of concrete depend on various factors, including the materials used and the mixing process. Concrete production involves the use of water at several stages. The water plays an essential role in mixing, curing, and the overall quality of the final product. It acts as a medium to activate the chemical reaction between the cement and the other materials in the mix, forming a paste that binds the aggregates together. Recently, there has been increasing interest in the potential benefits of using, e. m. treated water as an alternative to traditional tap water in concrete production. This unique interaction between water and electromagnetic radiation can potentially change the fundamental characteristics of concrete, including its strength, durability, and composition. Understanding the effects of this phenomenon is critical to the construction industry as it can lead to innovative approaches to improving the performance and durability of concrete structures.

Hydrogen bonding is believed to play a critical role in the formation and strength of concrete. Electromagnetic fields affect the structure of hydrogen bonds to improve the quality of concrete. Hydrogen bonding in concrete is essential for various properties, including workability, hydration process, strength development, and durability. Understanding and controlling hydrogen bonding interactions can help optimize the performance and properties of concrete in various applications. Several works have been carried out to evaluate the improved performance of concrete using magnetically treated water [1 - 5].

In the case of EM - treated water, the EM fields cause a restructuring of water molecules into clusters. Water molecules are polar, and EM the fields reorient and structure them by forming hydrogen bonds. In the preparation of concrete, the interaction of water molecules is crucial. Increasing the conductivity of the solution is one of the parameters related to its strength. Additionally, the formation of stable clustered structures enhances the parameters and durability of the concrete. That's why in advanced construction techniques and practices, the application of magnetic water plays an essential role in enhancing the physicochemical properties of materials.

This study attempts to elucidate the relationship between water exposed to electromagnetic waves and its effects on concrete properties. We aim to shed light on this relatively understudied aspect of concrete technology. Fourier transform infrared spectroscopy (FT-IR) and scanning electron microscopy (SEM) were used to investigate the effects of EM treated water EVOdrop on the homogeneity of concrete particles and improved hydrogen bonding in concrete.

EXPERIMENTAL

Device for electromagnetic-treated water

The concrete was prepared with water treated with electromagnetic waves. The scheme is illustrated in Fig. 1.

The frequency range is 20 - 40 kHz, the magnetic induction is B = 9000 Gauss, the volume of the beaker is 1 L.

Water parameters

There were two types of water for concrete preparation in our investigation:

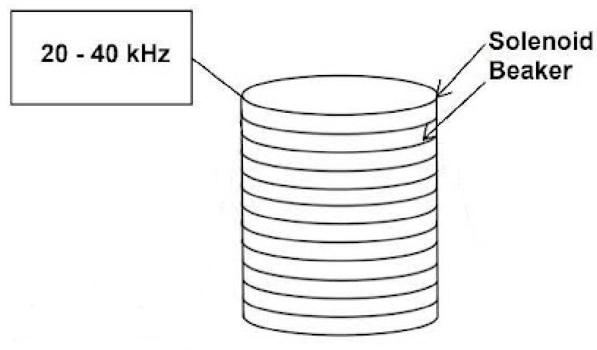

Fig. 1. Device with Beker and solenoid for water preparation, treated with 20 - 40 kHz EM fields.

1. Water with 81.5 ppm is marked as low ppm mineralization. This is defined as a Control sample 1 with low mineralization in our research.

Water treated with 20 - 40 kHz EM waves is defined as Sample 1.

2. Water with 807.4 ppm is marked as high ppm mineralization. This is defined as a Control sample 2 with high mineralization in our research.

Water treated with 20 - 40 kHz EM waves is defined as Sample 2.

Fourier Transform Infrared Spectral Analysis (FT-IR)

The studies were performed at the Institute of General and Inorganic Chemistry, Bulgarian Academy of Sciences (BAS), Sofia, Bulgaria. Different samples of concrete were measured on the Fourier-transform IR spectrometer Brucker Vertex (Brucker, Germany) and Thermo Nicolet Avatar 360 Fourier-transform IR. The spectral parameters: average IR - 370 - 7800 cm^{-1}; visible - 2500 - 8000 cm^{-1}; permission - 0.5 cm^{-1}; accuracy of wave number - 0.1 cm^{-1} on 2000 cm^{-1}.

Scanning Electron Microscopy

The device is Analysette 22 MicroTec Plus, Fritsch. The method shows wet diffraction. The range is 0.08 - 2000 µm. The number of applied certificates from 2023 are:

No. 3 - 0416/Control sample - high ppm.
No. 3 - 0417/ Control sample - low ppm.
No. 3 - 0418/ EVOdrop EM - EM high ppm.
No. 3 - 0419/ EVOdrop EM - EM low ppm.

RESULTS AND DISCUSSION

Results from FT-IR study of concrete made with low ppm EM treated water

Fig. 2 presents the Fourier - transform infrared spectra of the sample prepared with low ppm water and the sample prepared with water treated with EM fields from the EVOdrop device.

Fig. 3 shows the result of the difference spectra of concrete made with EM low ppm purified water and a low ppm water control sample.

The peaks detected in the IR spectrum of concrete produced with low ppm water are presented in Table 1.

Results from FT-IR study of EVOdrop EM high ppm samples

Fig. 4 shows the FT-IR spectra of the sample prepared with high ppm water and the sample prepared with water treated with EM fields from the EVOdrop device.

Fig. 5 describes the spectral difference result of concrete made with EM - treated water with high ppm and a control sample of water with high ppm.

Table 2 illustrates the bands in the IR spectrum of concrete made with high ppm water.

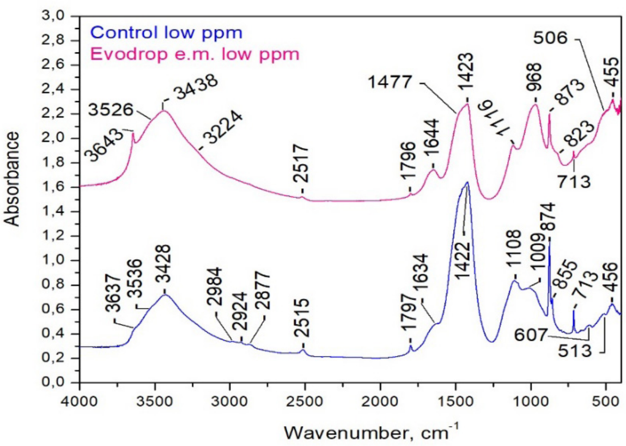

Fig. 2. FT-IR spectra of the sample using water with low ppm and sample using water treated with EM fields from EVO drop device.

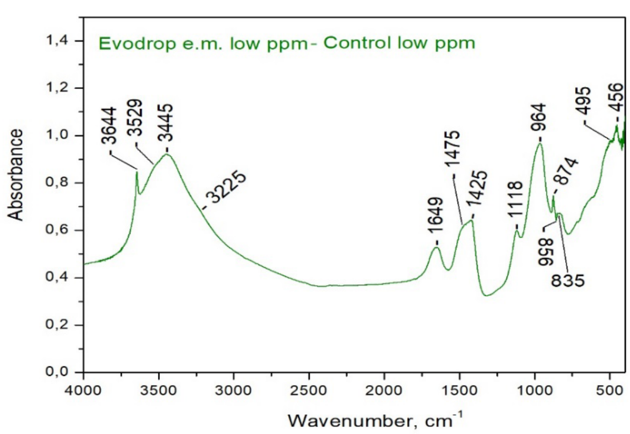

Fig. 3. The difference in the spectra of concrete made with EM low ppm purified water and a low ppm water control sample.

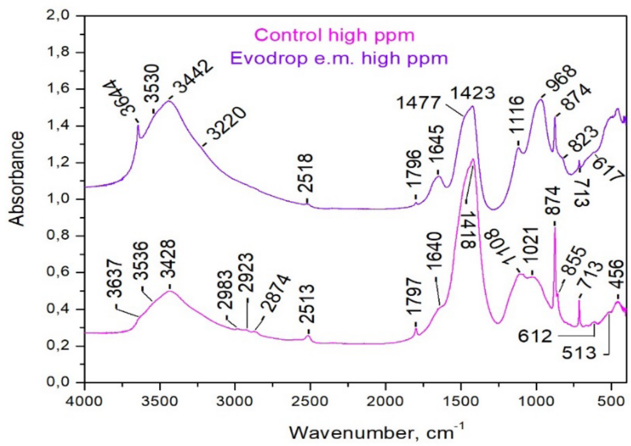

Fig. 4. FT-IR spectra of the sample using water with high ppm and sample using water treated with EM fields from EVO drop device.

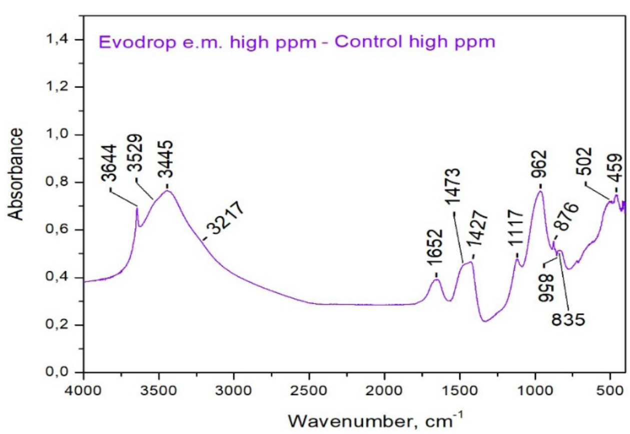

Fig. 5. Spectral difference result of concrete made with EM high ppm treated water and control sample of water with high ppm.

Table 1. Absorption bands in an IR spectrum of concrete made with low ppm water.

Absorption bands for concrete made with low ppm EM water		
Wavenumber, cm^{-1}	Wavelength, µm	Type
3644	2.74	strong
3529	2.83	strong
3445	2.90	strong
3225	3.10	medium
1649	6.05	medium
1475	6.79	medium
1425	7.02	medium
1118	8.95	medium
964	10.40	strong
874	11.42	medium
856	11.68	medium
835	11.98	medium
495	19.92	strong
456	21.77	strong

Table 2. Absorption bands in the IR spectrum of concrete made with high ppm water.

Absorption bands for concrete made with high ppm EM treated water		
Wavenumber, cm^{-1}	Wavelength, µm	Type
3644	2.74	strong
3529	2.83	strong
3445	2.90	strong
3217	3.11	medium
1652	6.05	medium
1473	6.79	medium
1427	7.01	medium
1117	8.95	medium
962	10.40	strong
876	11.42	medium
856	11.68	medium
835	11.98	medium
502	19.92	strong
456	21.77	strong

Analysis of results of peaks of EVOdrop EM low and high ppm samples received by FT-IR spectroscopy

The quality and performance of concrete, a widely used construction material, depend on the materials and the mixing process. Cement gets its strength from the chemical reactions between cement and water. The process is known as hydration. This complex process is best understood by considering the chemical composition of cement. Therefore, as an important component of concrete, water, which plays a prominent role in the hydration process, also affects its overall properties. The electromagnetic field structure of hydrogen bonds is known to improve the quality, strength, and durability of concrete [6].

The structuring of hydrogen bonds influences the following properties of concrete:

1. Water-cement paste. Hydrogen bonds in concrete are formed by interacting with water molecules and cementitious materials. As is well known, cement consists of compounds such as calcium silicate hydrates and calcium aluminate hydrates, which, as hydrates, contain water or its constituent elements. Usually, water is included in their structure by forming a complex with the cation in the ionic substances.

2. Water-silicate interactions: The main compounds in concrete, such as calcium silicates and aluminosilicates, contain silanol (Si - OH) groups on their surfaces. These groups form hydrogen bonds with water molecules.

3. Concrete may contain various additives, such as superplasticizers or air - entraining agents. They participate in interactions with water molecules by forming hydrogen bonds. Thus, these admixtures can affect the rheological properties and durability of concrete.

4. The concrete is a porous material that absorbs and retains moisture. Hydrogen bonding between the adsorbed water and the cementitious matrix affects the concrete's overall moisture content and distribution.

5. Hydrogen bonding in concrete is essential for various properties, including workability, hydration process, strength development, and durability.

As discussed above, cement is primarily composed of calcium silicates and aluminates, and the hydration process leads to the formation of different compounds.

FT-IR spectra of concrete mixtures with low and high ppm waters are very similar. All the absorption bands observed in the FT-IR spectra of cement are discussed below.

The peak at 3644 cm^{-1} was associated with OH stretching vibrations: of calcium hydroxide $Ca(OH)_2$ [7]. Calcium hydroxide (portlandite) is a standard hydration product of cement. The peak at 3529 cm^{-1} is attributed to water stretching vibration with intermediate hydrogen bond strength [8]. This peak may also relate to glycol. Glycol is commonly used as an additive in concrete to improve its workability and reduce the rate of moisture loss [9]. The stretching vibration of the carbonyl (C=O) group and CO_3 groups appears around 3529 cm^{-1} [10]. O-H stretching vibrations of water molecules absorbed in the cement structure are at 3217 cm^{-1} [11]. The absorption band at 3445 cm^{-1} is due to $CaSO_4$ of the ettringite phase of cement. Ettringite is a primary constituent of hydration of Portland cement concrete [12]. In the region of 3217 - 3225 cm^{-1}, stretching vibrations of the hydroxyl groups (-OH) are usually found [13]. The band around 1649 - 1652 cm^{-1} shows carbonyl group (C=O) [14] while around 1473 - 1475 cm^{-1} shows the bending vibration of carbonate ions (CO_3^{2-}) [15]. The specific locations of the latter bands may vary depending on factors such as the type of carbonate present, degree of carbonation, porosity, and composition of the concrete In concrete, carbonate ions are formed by a carbonation process in which carbon dioxide (CO_2) reacts with calcium hydroxide ($Ca(OH)_2$) to form calcium carbonate ($CaCO_3$). The extent of carbonation in concrete is important for assessing its durability and long-term performance. The bands around 1425 - 1427 cm^{-1} is associated with the hydration properties of concrete [16]. The bending vibrations of silicon-oxygen-silicon (Si–O–Si) bonds present in the silicate minerals in concrete, such as calcium silicates, are observed in the region of 1117 - 1118 cm^{-1} [17, 18]. The bending vibration of carbonate groups is observed around 962 - 964 cm^{-1} [19]. The 874 - 876 cm^{-1} band may be related to calcite [20] or Al-O stretching vibrations. The peak at 856 cm^{-1} is associated with calcium oxides (CaO) [21], obtained by heating of calcium carbonate ($CaCO_3$). The peak at 835 cm^{-1} is connected with OH groups in concrete [22]. The 502 cm^{-1} peak is essential for Ca/Si ratio in concrete [23]. The effects are from carbonate, hydrocarbonate, and silica ions. In this region may occur also Fe–O stretching vibrations. Si–O bending vibrations are observed at 456 cm^{-1}, indicating the presence of silicate groups in concrete samples [24].

A comparative analysis of the FT-IR spectra reveals that concrete mixtures with low and high ppm waters display typical spectral peaks when subjected to EM fields. These results can be explained based on the formation and strength of hydrogen bonds between water molecules and cement particles [25]. Indeed, the EM field provides structural stability to water by enlarging the size of the water clusters [26]. With the device with EM fields with B = 1000 Gauss, the water clusters are 23 water molecules in size. Analyses indicate the angle between two hydrogen-oxygen molecules of 104.5° decreases to 103.0° [27]. This effect stabilizes the existing clusters, especially hexagonal clusters with six water molecules. Mathematically, hexagonal clusters are the most stable structures [28]. Hexagonal clusters activate the hydrogen bonds at 1117 cm^{-1} [29]. During cement hydration, this peak indicates the cement quality [30].

The band at 886 - 897 cm^{-1}, related to the bonding between Ca^{2+} and CO_3 ions and $CaCO_3$ formation, appears upon activation with magnetic fields [31 - 36]. It's also characteristic during osmotic/diffusion processes [37, 38].

Scanning Electron Microscopy of concrete made with water treated with electromagnetic waves from an EVOdrop device

Control samples of concrete and EVOdrop EM treated water samples with low and high ppm, were prepared for SEM imaging (Fig. 6 and 7). SEM analysis used appropriate magnification and resolution settings to capture detailed microstructural information. Particle distribution and order between Control and EVOdrop EM treated water samples were analyzed and compared.

The first SEM micrographs display the Control samples with low ppm (Fig. 6a) and high ppm (Fig. 7a). Analysis of the image reveals a relatively disordered particle arrangement characterized by variations in size and irregular spacing. The second SEM photos of concrete, made with water with low ppm (Fig. 6b) and high ppm (Fig. 7b) treated with EM waves, exhibit a more prominent particle arrangement. There are better-quality crystals (CH), probably due to their better hydration [39]. This improved particle order can be attributed to the activation of hydrogen bonds after applying e, m waves to the samples. We suppose that the observed particle order may influence the strength and durability of concrete.

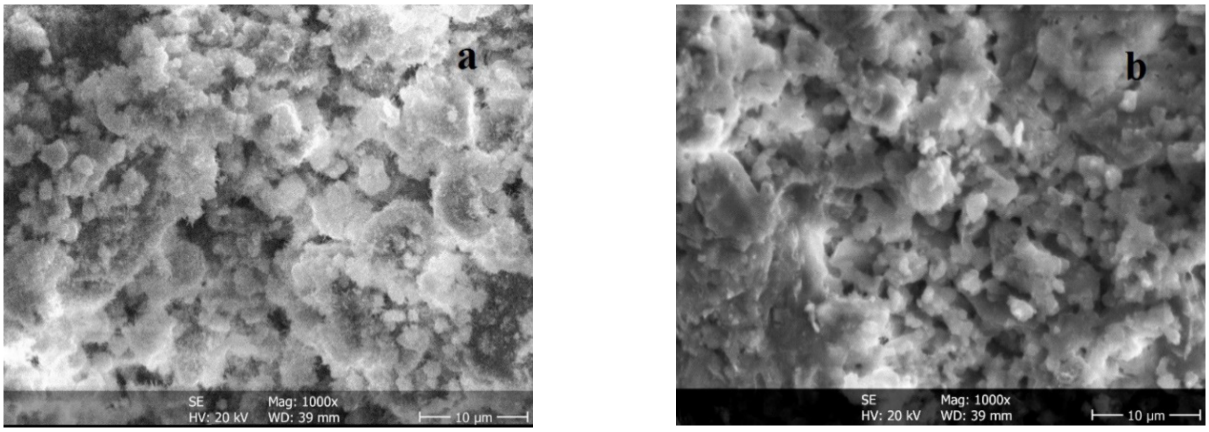

Fig. 6. SEM images of control samples of concrete (a) and EVO drop EM treated water samples (b) with low ppm.

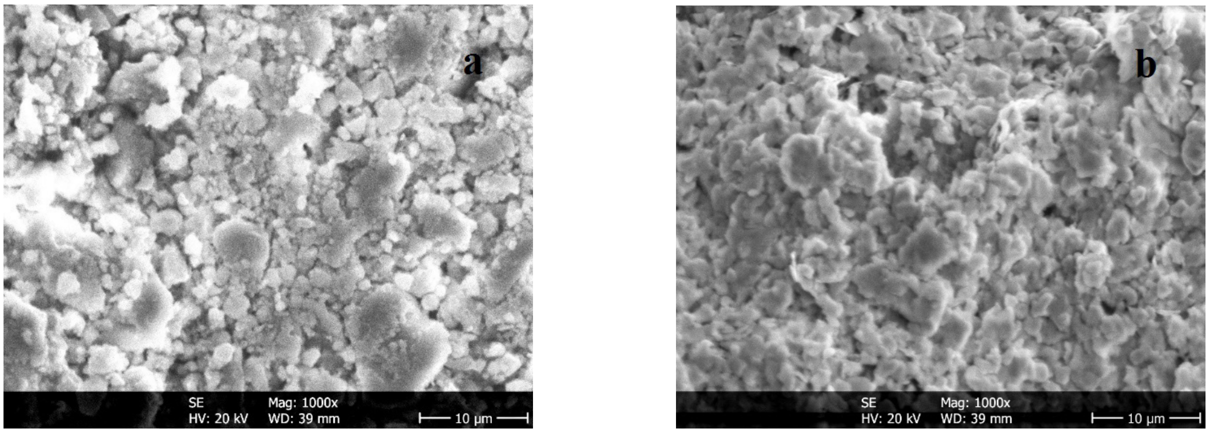

Fig. 7. SEM images of control samples of concrete (a) and EVO drop EM treated water samples (b) with high ppm.

Research with the SEM method shows that the concrete homogenizes better due to improved physicochemical properties and better hydration [40]. This improves the interaction of the chemical compounds of concrete. The strength and durability of concrete increases.

CONCLUSIONS

The present investigation aims to unveil the correlation between water exposed to electromagnetic waves and its influence on concrete properties. This is achieved by applying FT-IR and SEM examination on cement samples obtained with water treated using EVO drop's electromagnetic waves compared to control samples. A permanent magnetic field stabilizes water structuring and clustering, and water molecules can form organized structures, especially hexagonal clusters with six water molecules. These hexagonal clusters facilitate hydrogen bonding during cement hydration. That is why the application of EVO drop water treated with EM waves improves hydrogen bonding in concrete, which plays an essential role in the formation and strength of the material. Hydrogen bonding is a crucial factor in the performance of concrete structures. It occurs between water molecules and various components of the cementitious matrix. Hydrogen bonding significantly influences water-silicate interactions within the cementitious matrix. Essential compounds like calcium silicate hydrate gel play a crucial role in imparting strength to concrete. Applying electromagnetic waves enhances the hydrogen bonding of water molecules, particularly with effects on silicates. This strengthened hydrogen bonding with moisture is vital for ensuring the long-term durability of concrete structures. Optimizing hydrogen bonding is essential for improving concrete's overall performance and properties. On the other hand, hydrogen bonding plays a role in retaining moisture. This increases the concrete's ability to resist issues, including cracking, freeze-thaw damage, and chemical degradation of quality.

Through SEM analysis, it was observed that the electromagnetic treatment of water in cement production contributes to a final product characterized by a more interconnected and homogeneous structure.

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