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ANALYSIS OF THE EFFECT OF AMBIENT CONDITIONS ON CONCRETE COATINGS BY FOURIER TRANSFORM INFRARED SPECTROMETRY

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Abstract
Coatings are key industrial materials used to protect a variety of surfaces, including metals, wood, concrete and plastics. Their purpose is to provide protection against external influences such as corrosion processes, UV radiation, moisture and mechanical wear. However, despite their surface protection function, coatings are prone to degradation, which can have serious consequences for the surfaces they are intended to protect. This text will deal with the analysis of the degradation of coatings used to protect concrete surfaces by means of Fourier transform infrared spectrometry.

Keywords: *concrete; coating; surface protection; epoxies; acrylics; polyurethanes; infrared spectrometry; Fourier transform, degradation*

1. INTRODUCTION

Concrete coatings play a key role in protecting and decorating concrete surfaces in a variety of applications, from construction projects to industrial facilities. These coatings are designed to protect concrete from corrosion, weathering, UV rays, chemicals and mechanical wear [1, 2]. However, degradation of concrete coatings can reduce their effectiveness over time, which negatively affects the durability and aesthetics of concrete surfaces.

1.1. Mechanisms of paint degradation on concrete

Degradation of coatings on concrete can be caused by a variety of factors, including:

1) Corrosion damage: moisture and aggressive chemicals can penetrate through the coating and cause corrosion damage to the concrete surface. This can lead to peeling of the coating and subsequent damage to the concrete.

2) UV radiation: Solar UV radiation can cause hardening and cracking of the coating on the concrete. This leads to loss of surface protection.

3) Mechanical wear: Physical wear, including friction, impact and abrasion, can damage the coating film, causing it to gradually wear away.

4) Chemical influences: Exposed concrete surfaces may be exposed to chemicals that can degrade the coating film, which can reduce its effectiveness.

5) Biological growth: Moist environments can promote the growth of microorganisms such as mould and algae, which can erode the coating film.

1.2. Consequences of paint degradation on concrete

Degradation of coatings on concrete can have serious consequences:

1) Loss of protection: degraded coating loses its ability to protect the concrete surface from external influences, increasing the risk of corrosion and other damage.

2) Deterioration in appearance: Fading, hardening and cracking of the coating film can lead to deterioration of the aesthetics of the concrete surface, which is particularly important in commercial and residential applications.

3) Repair Costs: Materials and labor costs can be higher for repairing and restoring degraded concrete.

4) Reduced Durability: Degradation of coatings can shorten the life of the concrete surface, leading to the need for more frequent maintenance and renovation.

1.3. Prevention of paint degradation on concrete

Preventing the degradation of coatings on concrete is a key objective in maintaining the durability and aesthetics of concrete surfaces. Some measures include:

1) Proper coating selection: choose a coating that meets the specific operating conditions and protection requirements of the concrete.

2) Thorough surface preparation: Ensure the surface is clean and prepared for better adhesion before applying the coating.

3) Regular maintenance: regularly inspect and maintain the concrete surface and the coating film.

4) Quality application: follow recommended procedures for paint application to ensure durability.

Degradation of coatings on concrete is an inevitable process, but with careful prevention and maintenance, this degradation can be minimized. Proper selection, application and maintenance of coatings are essential to maintain the durability and aesthetics of concrete surfaces in a variety of applications.

1.4. Frequently used material bases of coatings for concrete protection

1.4.1. Silicones:

Silicones are frequently used coating materials with unique properties. These coatings usually have an acrylic dispersion as a binder, which is enriched with a solvent-free silicone emulsion. This combination allows for a coating that is not only water repellent, but also vapor permeable. An important feature of silicone coatings is their ability to resist water. This means that a surface that is coated with this type of coating will resist water penetration and thus protect the substrate material from moisture. This water repellency is particularly useful outdoors where surfaces are exposed to rain, moisture and weathering.

A significant advantage of silicone coatings is also their ability to allow vapour permeability. This means that while they prevent water penetration from the outside, they allow water vapour to escape from the inside. This is key to maintaining the optimum condition of the surface and substrate material, as it allows moisture to vent and prevent condensation inside the structure.

Silicone coatings are often used on various types of surfaces, including building facades, roofs, concrete structures and other exteriors. Their properties ensure that surfaces remain resistant to adverse weather conditions while maintaining suitable microclimatic conditions inside the structure.

1.4.2. Epoxies [3, 4, 5]:

Epoxies are specific coating materials that are characterized by high strength and hardness, which greatly increases the physical resistance of the surface to which they are applied. These coatings are typically composed of two basic components - a base and a hardener. The combination of these two components results in a chemical reaction that produces a tough, durable coating.

One of the main benefits of epoxies is their ability to resist chemicals that can be aggressive to concrete surfaces. This chemical resistance includes resistance to various acids, alkalis and other aggressive substances. As a result, epoxies are often used in industrial environments where high chemical resistance is a key requirement.

Another important aspect of epoxies is their adhesion to concrete if proper substrate preparation is carried out. This means that the epoxies adhere well to the concrete surface, ensuring the durability and reliability of the coating.

However, it is important to note that epoxies have low UV resistance, which means they are not ideal for exterior use. Sunlight can cause them to degrade and lose their aesthetic appearance. Therefore, epoxies are more commonly used indoors or on surfaces that are not exposed to direct sunlight.

1.4.3. Polyurethanes [6, 7, 8]:

Polyurethanes are another interesting group of coating materials that have several distinguishing characteristics. They are related to epoxies but differ from them in the flexibility they offer after curing. This flexibility is a key feature of polyurethanes, which means that they are able to move with the surface to which they are applied and adapt to various deformations and movements.

Polyurethanes are also known for their weather resistance. This means that they are able to maintain their properties and quality even when exposed to sunlight, rain, humidity and temperature fluctuations. Due to this resistance, polyurethanes are often used in exterior applications, such as coatings on exterior surfaces of buildings, bridges and other structures exposed to adverse weather conditions.

One of the outstanding applications of polyurethanes is their ability to bridge mobile cracks. Thanks to their flexibility, they are able to "breathe" with the surface and fill cracks that may appear in concrete or other materials over time. This increases the long-term durability of the surface protection and helps prevent the penetration of moisture and aggressive substances into the structure.

Overall, polyurethanes are a great choice for coating systems that require flexibility, weather resistance, and the ability to adapt to surface movement. Their properties make them suitable for various types of construction projects where it is important to maintain the quality and durability of the surface protection.

1.4.4. Dispersion:

Dispersions are a complex concept that has contributed significantly to the boom in water-based materials in recent years. This term refers to mixtures where one substance or more substances are uniformly dispersed in another substance to form a homogeneous mixture. In practice, this means that different chemical components are carefully mixed to create a product with uniform properties and characteristics.

One of the main factors contributing to the growing popularity of water-based dispersions is their wide variety of material bases. These include acrylics, polyurethanes, epoxies and many others. Each of these foundations has its own unique properties and uses, allowing engineers and designers to select the material that best suits the specific requirements of their project.

Dispersions are characterized by a high variability of properties. This means they can offer different levels of strength, weather resistance, chemical resistance and aesthetic appeal. This flexibility is key because it allows the material to be adapted to specific conditions, which can be very diverse depending on the project.

As a result, dispersions are an increasingly popular solution for many sectors, including construction, industry and infrastructure renewal. Their extensive use allows engineers and architects to choose materials that optimally meet specific needs. Dispersions thus play a key role in modern coating technologies and contribute to the protection and improvement of various surfaces.

2. ANALYSIS METHOD

Fourier transform infrared spectrometry (FTIR) is a powerful analytical technique in the field of chemistry and materials science that enables the detailed study of the molecular structure and chemical composition of substances. This method uses infrared radiation, which is electromagnetic radiation with a lower energy than visible light, to obtain information about the bonds between atoms in molecules.

The principle of FTIR is the detection of infrared radiation that has passed through or been reflected from a sample. The key element of this technique is the Fourier transform, which is a mathematical method that allows the signal to be converted from the time domain to the frequency domain, thus obtaining the infrared spectrum. This transformation is achieved by the interference of light rays after passing through the interferometer. FTIR spectrometers can measure entire infrared spectra at once, which is a big difference from traditional dispersion spectrometers.

The advantages of FTIR spectrometry include high sensitivity, speed, and the ability to perform quantitative analysis. This technique is used in a wide range of applications, including the chemical industry, food, pharmaceutical, biological and forensic sciences. FTIR can be used to identify unknown substances, analyze chemical reactions, perform quality control tests, and study material properties.In addition, FTIR spectrometry is often combined with other techniques, such as microscopy, to enable the analysis of microscopic samples, which is useful, for example, in the study of biological samples or materials on surfaces.Samples were analyzed on a Nicolet iN10 instrument and spectra were evaluated in the Omnic Picta software environment.

3. EXPERIMENTAL PART

3.1. Analyzed samples

A total of 7 samples (D-6 – D-12) were analyzed. Samples D-6 – D-9 were treated with acrylic-based paint, samples D-10 – D-12 were treated with epoxy resin-based paint. The analyzed samples were long-term exposed to the outdoor environment.

3.2. Setting up the experimental conditions

Spectrometer: Nicolet iN10
Source: IR
Detector: MCT/A
Beamsplitter: KBr
Sample spacing: 2.0000
Digitizer bits: 24
Mirror velocity: 2.5317
Aperture: 150.00
Sample gain: 1.0
High pass filter: 200.0000
Low pass filter: 20000.0000

Number of sample scans: 256
Sampling interval: 50.12 sec
Resolution: 8.000
Levels of zero filling: 0
Number of scan points: 4384
Number of FFT points: 4096
Reference frequency: 15798.7 cm-1
Interferogram peak position: 2048
Apodization: N-B Strong
Number of background scans: 256
Background gain: 1.0

4. RESULTS

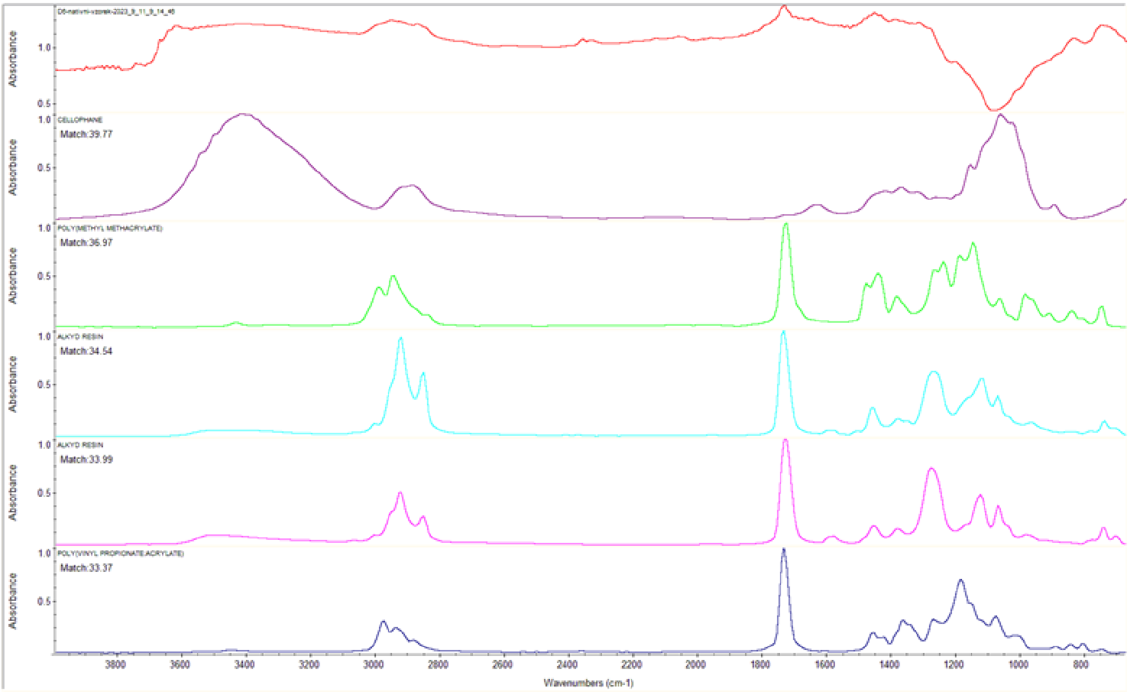

***Fig. 1**: Infrared spectrum of a sample provided with an acrylic coating (D-6, red) with a characteristic change (shift) typical of a degraded coating.*

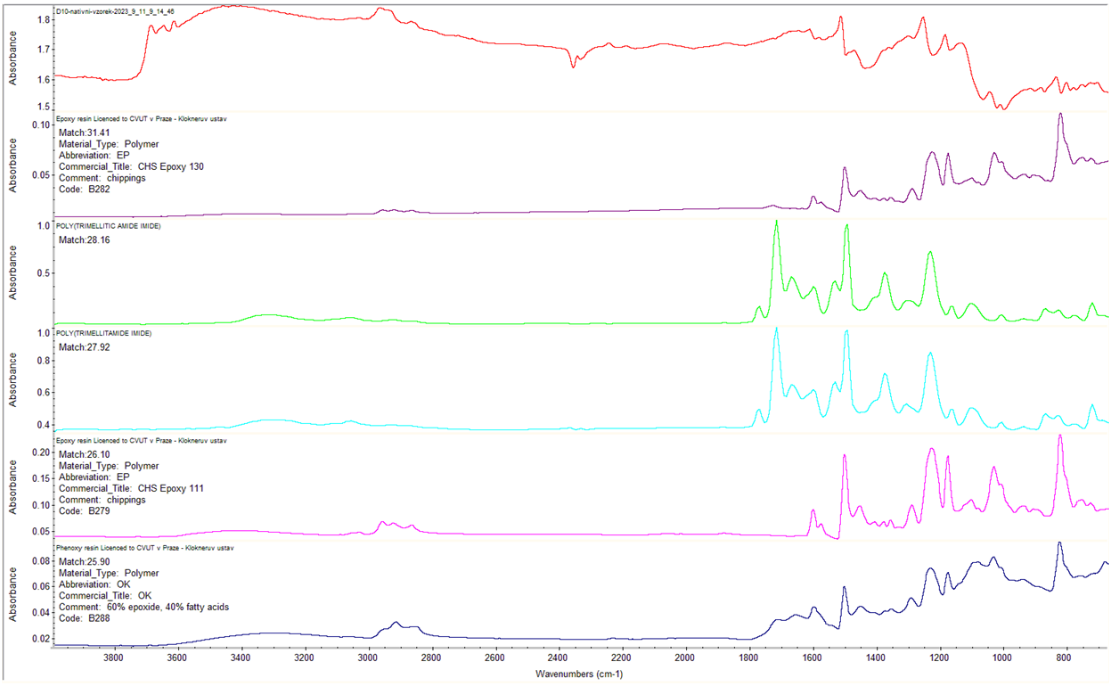

Fig. 2: *Infrared spectrum of a sample provided with an epoxy coating (D-10, red) with a characteristic change (shift) typical of a degraded coating.*

5. CONCLUSION

Changes in the infrared (IR) spectra of paints due to aging can indeed involve shifts in the positions of certain absorption bands or peaks. These shifts can provide valuable information about the chemical and structural changes that occur as paint ages. Here are some examples of shifts that can occur in the IR spectra of aged paint:

Shifts in peak positions: As paint components undergo chemical changes, the vibrational frequencies of functional groups can change. This can result in shifts in the positions of absorption peaks in the IR spectrum. For example, if oxidation occurs, causing the formation of new oxygen-containing functional groups, you may observe shifts in the positions of peaks associated with carbonyl (C=O) or hydroxyl (OH) groups.

Band broadening: As paint ages, the vibrational bands in the IR spectrum can become broader. This broadening can be indicative of increased molecular disorder or distribution of molecular species within the paint. It may be particularly noticeable for bands associated with complex polymer structures.

Peak intensity changes: Aging can lead to changes in the intensity of specific absorption bands in the IR spectrum. For instance, if certain paint components are breaking down or being depleted, the intensity of corresponding peaks may decrease. Conversely, the appearance of new peaks due to chemical reactions may result in increased intensity in certain regions.

Multiple peaks: Aging can sometimes result in the appearance of multiple peaks within a specific functional group region. This is often observed when different chemical species or structural configurations coexist within the aged paint, leading to multiple absorption features in the IR spectrum. Shifts in Fingerprint region: The fingerprint region (usually below 1500 cm^{-1}) of the IR spectrum contains complex vibrational patterns unique to a molecule or material. Aging-induced structural changes can lead to shifts or alterations in the fingerprint region, which can provide detailed information about the evolving molecular structure of the paint. Shifts due to pigment changes: Changes in the crystalline structure or chemical state of pigments within the paint can result in shifts in the IR spectrum. These shifts may be related to alterations in the vibrational modes of the pigments themselves.

Overall, the specific shifts observed in the IR spectra of aged paint will depend on the composition of the paint, the nature of aging processes (e.g., oxidation, hydrolysis, photodegradation), and the duration of aging. Analyzing these shifts can help in understanding the degradation mechanisms and assessing the condition of aged paint.

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