THE EFFECTS OF THE ENVIRONMENTAL FACTORS ON THE PERFORMANCE OF THE RENDERINGS: A REVIEW

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Abstract

The renderings are the last coatings of the buildings and the renderings face the environmental effects directly thus they are more effected by the environmental factors than the other components. The performance requirements of the renderings are determined by the environmental factors. The main goal is to set and fulfil these requirements for the best performance of the renderings.

These environmental factors are U.V, the moisture, thermal conditions, CO_2, SO_2 or SO_3, Cl ions, acids and the salts. These environmental factors have peculiar degradation mechanisms but at last the degradations of the renderings are the same such as cracking, disintegrating, shrinking or corrosion.

As examples of the degradation mechanisms of the environmental factors; U.V breaks the bonds between the polymers of the polymer based renderings and the renderings spoil. CO_2 penetrates through the renderings and form carbonation so the volume changes and the renderings disintegrate. As a result of Sulphur affect, the corrosion occurs then the renderings cannot supply the requirements. The penetration of the driving rain through the renderings is hazardous if the evaporation of the water is not sufficient. The moisture harms the structure of the renderings by forming damp, mould growth and spoiling the adhesion between the substrate and the renderings and the structure of the renderings by the freeze-thaw. Due to the thermal changes, the renderings shrink or expand. If these events repeat, the renderings spoil.

Besides, the acidic or base character of the renderings form degradation mechanisms, as well. On the other hand, the salt ratios of the renderings should be considered, too since high salt ratios form crystallization in the renderings then this crystallization compress surround and the renderings disintegrate.

Shortly, investigating the performance of the renderings is the most important topic because the effects of the environmental factors form different degradation mechanisms and the renderings spoil so the renderings are not capable of supplying the performance requirements.

When the performance of the renderings decrease, degradation mechanisms continue to harm the substrate. Consequently, the performance of the building will be lost. This work helps knowing the environmental factors and their degradation mechanisms so that we can take precautions. The performance of the renderings means to answer the requirements. Understanding the environmental factors and their degradation mechanisms, it is possible to get the renderings which supply the required functions.

Keywords: Renderings, performance, degradation, environmental factors, plaster

1. Renderings

1.1 Definition

External rendering is among the oldest techniques in building and there are a lot of examples from ancient Egypt, Assyria, Rome and Europe [1].

It is defined as a mortar used to smooth and protect the surfaces of the built of stone or brick. Renderings are a coating applied on the walls with a determined thickness.

The renderings are a coating system made of a binding material, fine aggregate and water. Besides, some additives are used for a specific color, the resistance to the rain and the frost, improvement of workability. The binding materials are cement, lime, gypsum and polymer based materials like acrylic and PVA. The aggregates are coarse and fine sand, the marble dust, caoloen and talk [2].

The size of the aggregates, especially sand is normally no more than 1/3 to 1/2 of the thickness of the layer. Also, the grain size distribution of the sand should be continuous thus all the spaces between the larger particles are filled by smaller particles. On the other hand, especially the sand does not contain humus (organic material produced by the decay of plants) because there will be chemical reactions to spoil the structure of the renderings. The sand should not include more than 10 % volume by clay or silt since they give higher shrinkage so the cracks occur [1].

1.1.1 Internal Plastering

The internal plastering is applied to protect the internal walls, hide the brick or concrete appearances, not to hold the dust and the dirt and to support a cleanable, decorative and aesthetic surface. The internal plasters are covers suitable to the paint and the wall paper.

1.1.2 External Rendering

In order to protect the external walls and building from atmospheric conditions and support an aesthetic appearance convenient to the character of the building, external renderings are applied on the external surface of the building.

1.2 Classification of Renderings

The renderings are classified according to the binding materials and the production methods.

1.2.1 Binding Materials

- Mineral Based Binding Materials

  Cement, lime, gypsum are mineral based binding materials. (Traditional renderings)
- Synthetic Resin Based Binding Materials

  The binding materials are polyvinyl acetate, acrylic polymer or copolymer. The renderings can be applied with their undercoats. Water does not penetrate through this rendering due to the dispersion property of the renderings. The thickness of the synthetic resin based renderings is 1-4 mm according to the substrate and the application methods. They have own tissue and decorative property and they can be applied on the walls by trowell, roll and sprays. The synthetic based renderings harden more quickly and are more elastic than the mineral based renderings. Actually, synthetic based renderings have low water permeability and low vapor diffusion properties [3].

1.2.2 Production Methods

- The traditional renderings

  The renderings which are produced at the site or close to the site. The binding materials are cement, lime, and gypsum. The traditional renderings are classified according to the materials, application methods and the appearance.
- The ready-made renderings

  The renderings which are produced at the factory for the facade coatings. They can be thinned with water and be applied directly on the concrete and the precast surface. The binding materials are polymer based materials. Copolymer binding materials support the highest resistance to U.V, alkali reactions, water and oil. Some additives or coarse and fine aggregates are used to support durability to the light, heat and water, to prevent decomposition and loss of color by the sun and the growth of the bacteria and mould.

1.3 Application

During the application of the renderings, there are two principals to be taken into account for the performance of the renderings:

1. The properties of the renderings should be known before the application.
2. The adhesion between the rendering and the substrate.

The first rule of the application of the renderings is not to make a strong layer on the weak layer. According to this rule, every rendering layers weaken from the substrate, namely the dosage of the cement should be reduced, but the finished layer must be resistant enough to the environmental effects.

The thickness of the external renderings is 2-3 cm, the thickness of the internal plasters is 1,5-2 cm. However, on the rough surfaces, these thicknesses should be increased or metal mesh laths should be used. After the hardening of the concrete substrate, the rendering should be made and at first the internal plaster is applied then the external rendering is applied. Before the application the rendering, the strength, the tissue, the porosity and water absorption of the substrate, the amount of the salts, the transfers of the water vapor and heat through the substrate must be investigated. at the first stage of the application, the surface of the substrate should be cleaned or acrylic and latex based undercoats are used for the improvement of the adhesion. During the application of the rendering, the temperature of the environment must be controlled and the temperature is not below 5^0C or not above 35^0C. After the application of the renderings, they should be irrigated.

The application changes according to the surfaces of the substrates [4];

- The concrete surface

  The roughness of the concrete is low. Unless ready-made renderings are used, the surface must be rough. The rendering and the concrete should clamp together so a good adhesion is obtained. Since concrete does not absorb water, it effects the application and the performance of the renderings positively. As the mortar is fluidity, application of the rendering on the wall is easy so the rendering is applied everywhere and there are no voids and the adhesion with the concrete is good.

- The brick surfaces

The brick has low toughness, too. We should sprinkle water for the holding of the rendering on the brick. Also, the clay brick is non-porous material so the brick does not absorb water.

- The autoclaved aerated surfaces

  These surfaces are smooth, but water absorption of these surfaces are high because of their porous structure. Before the application of the renderings, the surfaces must be saturated with water. The thickness of the rendering must be high to be durable to the environmental effects.

- Insulation covered surfaces

  Insulation materials should increase the conservative of the renderings. Insulation materials absorb moisture and heat so the effects of these conditions are minimized and the long-term performance of the renderings is supplied. The mesh lath is used to prevent the problems of the different expansions of the insulation material, the rendering and the substrate.

2. The Environmental Factors and their Degradation Mechanisms

The performance of building components is influenced by both the material composition, as well as the environmental conditions which they are exposed. The environmental factors have played an increasing role in how a building's performance is measured and characterizing the durability potential of the building components. It is necessary to identify the degradation mechanisms of these factors in the design phase of a building because the degradation mechanism is a highly complex system influenced by a large number of environmental factors and degradation process effect the structure of the buildings.

There is a need to measure and quantify the environmental factors which form degradation mechanisms for the design of the buildings since we should know the performance to these degradation processes is or not sufficient for the requirements. It is necessary to define the environmental factors in order to characterize the environments and develop performance tests so Table 1. demonstrates the examples of the different mechanisms of environmental factors.

2.1 U.V.

UV has an important effect for deterioration of some organic materials. Especially, UV radiation determines the performance of the polymeric materials used in external renderings. UV radiation breaks the polymer bonds by decomposing the carbo-hydrates like cellulose, then carbon remains oneself so the color darkens and the materials break up. In plastic materials, UV radiation forms depolimeration effect. UV causes the change of the color by spoiling the structure of the color pigments. When investigating the UV effect, the sensitivity of the materials to specific wavebands is important. As a general rule, the radiation shorter than about 360 nm causes yellowing, micro cracking and embrittlement, but radiation longer than 360 nm causes fading [5].

However, the UV effect is just not thought oneself, also the combination with moisture, water or temperature has a great effect on the external surfaces. The combination effect of water and UV radiation causes erosion and fading of the surface of some types of polymer and it is called as chalking. Besides, the UV effect varies with the air pollution, local weather, time of day. Nowadays, the hole in the ozone increases UV effect [6].

Table 1. Examples of degradation mechanisms of environmental factors

Degradation Factor	**Action**	**Reactions**	**Materials possibly at risk (examples)**	**Sub-division of factor**
Solar radiation U.V.	Products are genarally protected from UV radiation			
Thermal	Solar heat gain causing rise in internal temperature	**Thermal expansion** -bowing or twisting temporary permanent -loss of bond **Cyclic expansion/contraction** -fatigue damage	Metals Plastics Thin sheet materials Multilayer materials Concrete Mechanically fixed product Bonded product	Climatic zones Orientation of building or building compartment

Differential temperatures Internal/external Internal/internal	Thermal expansion/contraction Thermal expansion/contraction	**Mechanical** -bowing -twisting -delamination **Mechanical** -bowing -twisting -delamination	Thin panels Multilayer materials Thin panels Multilayer materials	Climatic zones Internal conditions Internal conditions
Localised heating	Localised chemical/physical degradation Localised thermal expansion/contraction	**Chemical** -embrittlement -change in appearance **Physical** -embrittlement -change in appearance -loss of thermal properties **Mechanical** -bowing -distortion -delamination	Plastics Thin panels Multilayer materials	Temperature of heat source Continous/intermittent
Depressed temperatures	Thermal contraction	**Mechanical** -shrinkage	Materials generally	

2.2 The Moisture

Rain effect plays an important role in porous materials especially, the renderings. The driving rain can support the effects of the moisture When rain strikes a facade, a film of water forms on the surface and the wall absorbs water. The wind pressure is added to this suction. If there are cracks in the surface, water can run into the wall easily. Factors that affect rain penetration are the properties of the wall materials, the amount of water hitting the wall and wind pressure over the wall. Besides, the intensity of driving rain on any surface determines whether a water film will be formed and the thickness of that film. After the rain stops, this water evaporates but some water is collected between the wall and the rendering. This water causes losses of adhesion, further cracking, complete disintegration of the rendering through the frost action or dampness. It may also cause deterioration by salt decomposition, mould and rot, chemical conversion and biological attack [7].

The moisture migration in building materials is extremely important for the characterization of behavior in relation with performance and degradation of appearance. The moisture is one of the primary causes of the damage observed on the envelope of buildings. The moisture or water vapor diffusion through the external renderings and the walls occurs due to the water vapor partial pressure differences between the interior and exterior environment and the water vapor partial pressure is depending on the value of temperature and relative humidity. This is the main kind of moisture transfer under normal conditions. The different layers resist the moisture transfer due to their different material properties and resistance factors. The vapor diffuses relatively easy through the layers with a low water vapor diffusion resistance factors but it is accumulated in front of the layers with high resistance factors like mineral renderings. Extraordinary amount of moisture is captured in the wall due to design or construction failures such as using wrong, feeble, poor quality materials or not controlling the design process. As moisture is affecting the physical performance of the renderings, it can cause important defects. Excessive moisture accumulation in the rendering decreases the heat resistance of materials. Moisture accumulation on the inner surfaces causes water stains, peeling parts and mold growth. Mold growth in turn has effects on air quality and user's health besides that mould growth causes a darkening of the color [6].

The performance of the renderings is many respects related to their moisture content. The moisture content is defined as the ratio of the weight of water to the weight of the dry material. When there is a high moisture content in the rendering, the moisture gathers and becomes fluidity and spoils the binding property then the renderings spill out.

The moisture performance of renderings, porous materials is mainly determined by capillary suction of water under wind pressure. Amount of driving rain impinging an external rendering depends on the meso-level climate conditions such as horizontal rainfall intensity, wind direction and speed, geographical location of the site, the design of the building and conditions around the building.

The moisture is the major atmospheric agent which forms chemical, physical and biological degradations for the external renderings. The degradation mechanisms of the moisture are surface cracking, change in appearance such as staining, white salt deposits on the rendering, loss of adhesion, embrittlement, frost spalling, fading, yellowing, loss of water repellency, deterioration by attacking the calcium compounds of the substrate, dirt pick up, stains of biological growth and decrease in thermal performance.

Wet walls subjected to freezing and thawing that may cause cracking, crazing and disintegration. When water freezes, it expands and when it thaws the effects of this expansion can become apparent in the form of frost damage. If sufficient water is entrapped in the pores of the rendering, frost damage occurs. At the lower temperatures water is frozen. The rate of the thermal change in the rendering is important, as well. also the cycles of freezing and thawing determines the frost damage because after excessive numbers of the cycles damage the renderings [6].

The complete impermeability of the rendering to water is not necessarily advantageous in all situations because the rendering can be permeable to water vapor and the rendering materials in particular have this property and allow the substrate to breathe. This property of breathing allows the substrate to lose water through evaporation but to resist the uptake of moisture during damp periods [8].

2.3 Thermal conditions

The temperature changes between outdoors and indoors or the temperature differences between the soil and the basement form cracks. These thermal stress cracks are seen mostly in mass concrete structures. Shrinkage supports the formation of the cracks since the shrinkage occurs because of the evaporation of the water from the surface or the inner parts of the renderings so the volume of the renderings decrease and cracks occur. Besides, extension of the materials due to the thermal changes form cracks, as well.

The different expansion characteristics of the rendering materials form the expansion problems so the thermal expansion coefficients of the materials are important to understand the thermal effects of the thermal conditions. The thermal expansion coefficients of the renderings depend on the mineralogical composition of the sand, sand/cement ratio and water amount of the cement paste [8].

2.4 CO_2

The effect of CO_2 on the external surfaces is called carbonation. The carbonation is the loss of alkalinity occurring to penetration of CO_2 from the atmosphere, especially in industrial places. The rendering is a porous material and allows an interchange of gas between the pores and the atmosphere, so allowing the transport of CO_2 into the structure. Here the CO_2 is absorbed by the structure so forming a slightly acidic solution which neutralizes the alkalinity of the rendering or converting calcium hydroxide and other cement hydrates into insoluble carbonates and this result in a reduction in the pH of the concrete. If this process continues, the total alkalinity will ultimately be neutralized and the rendering will be unable to provide protection for the substrate. The continuity of carbonation depends on the amount of moisture and oxygen available. The rate of the carbonation depends on the quality and the type of the rendering, the level humidity in the rendering, the content of CO_2 in air (carbonation increases rapidly with increasing CO_2 amount) [8].

2.5 SO_2 and SO_3

SO_2 is considered a major contributor to acid rain and environmental acidification. SO_2 transform in the atmosphere to SO_3 which may be also be both wet and dry deposited. SO_3 degrades materials that are susceptible to acid attacks.

2.6 Cl ions

The ingress of Cl is the major cause of deterioration of marine structures and bridges subject to de-icing salts. Cl penetration into the renderings is not normally serious except for those subject to a marine atmosphere or adjacent to highly trafficked roads. Cl ions diffuse into the renderings in solution, too. Cl ions form HCl with hydrogen ions and spoil the structure of the renderings.

2.7 Acids

When talking the effects of the acids on the renderings, it is important to know pH values of the renderings. If the pH values are below 4.0, the rendering deteriorates rapidly. The rate of the diffusion of the acid through the rendering and the reaction rate of the acids with the rendering effects the performance of the renderings. Especially, the chemical composition of the cement determines the effects of the acids [9].

Acids most important to the deterioration of materials through atmospheric corrosion are sulphuric acid (H_2SO_4), nitric acid (HNO_3) and hydrochloric acid (HCl). Sulphuric acids are easily deposited on external renderings. The pH values on the surfaces close to the major pollution sources may be very low, promoting corrosion attack on the renderings. Nitric acid is easily deposited, too and if deposited on the surfaces, it is very aggressive and attacks both native and synthetic polymers. Especially, the sulfuric acid reacts with $Ca(OH)_2$ to form gypsum then the formation of the gypsum causes volume expansion so the renderings disintegrate. Moreover, the reaction between C_3A and the occurred gypsum supports the formation of the ettrengite volume expansion occurs and inner pressure increases.

2.8 The Salts

An important effect of salts is that, due to their hygroscopicity, they may, if deposited on the surfaces increase the moisture content and prolong the wetness periods of the renderings. Besides, that salts are more or less aggressive. Recrystallization of salts in micro pores of porous materials such as rendering may cause enough tensions for the material to decompose.

3. The Performance Requirements of the Renderings

The performance statement is only one aspect of the requirements of the buildings. The requirements should be stated in terms of performance based on the test results than in dimensions, detailed methods or specific materials.

The performance requirement of the renderings is a quantitative statement giving the level of performance required to meet the user needs or expectations for the renderings [10].

The main reason for applying the renderings is to protect the substrate from atmospheric conditions. The atmospheric conditions have the hazardous degradation mechanisms to the external surfaces or the renderings. The requirements of the renderings resist these atmospheric conditions and support the performance of the renderings over a long time. In other words, the performance requirements of the renderings are an ability of resisting or accommodating the agents and mechanisms of deterioration in the environment and perform the required functions. These performance requirements are listed [8];

- Controlling or arresting the carbonation of the renderings.
- Inhibiting the chloride penetration.

- Controlling the moisture content of the substrate.
- As a supplement to inadequate substrate cover.
- Dealing with excessive mould growth.
- To maintain the substrate in a dry condition in order to slow the rate of alkali/aggregate condition and to prevent the damages of the moisture.
- Protecting dry, dirt-free and hygienic conditions.
- Protecting the substrate from sulphate attack, acid or other industrial pollutants.
- The renderings must not expand or shrink or crack due to the heat changes.
- The color of the renderings must not fade and flow.
- Being elastic to prevent the cracks occurred from the volume changes.
- The renderings must be capable of bridging any such cracks (accidental loading, shrinkage, early age contraction and other temperature effects) at the application stage.

Besides, covering these requirements, the renderings have some required properties. These are;

- The renderings must be impermeable to water, vapor, moisture or some gases.
- A good adhesion with substrate to avoid flaking and blistering.
- The renderings must be slippery to flow water.
- Suitable to the economic conditions for making the requirements.

The majority of the renderings have a finite life and would need recoating after a number of years.

4. Test Methods

4.1 The Test Methods for U.V.

The samples are put under the U.V bulbs which has different values or the samples are settled under the sun directly for a determined time. After that time, the degradation is investigated.

4.2 The Test Methods of CO_2 and The Carbonation

The effect of CO_2 on the material is the carbonation by effecting the basic components with the hydrolysis. The carbonates formed by the carbonation accumulate on the renderings and stains occur. The carbonation has a great role on the decomposition of the renderings so testing the carbonation is important for the performance of the renderings. Some tests of the different investigations are explained [8];

BRE (Building Research Establishment) tests for CO_2 diffusion are made on a number of some surface treatments system. In the initial tests, 50*50*25 mm mortar blocks are used. The blocks are exposed in a chamber of the test apparatus to a 15 % CO_2 in air mixture at 2 humidity (85 % - 60 % RH) at 23^{0}C for a period of 14 days. The blocks are weighed at intervals over the period of the test and the weight changes are calculated for each blocks. At the end of the test, the blocks are split, the fresh exposed surfaces sprayed with 1% phenolphtalein solution and the depth of carbonation is measured.

PRA (Paint Research Association) test for CO_2 diffusion are made on free films or coatings applied to a paper in an apparatus that measure directly the CO_2 diffusion the paint film. The films are put in a test cell and a 20 % CO_2 in air mixture at 75 % and 25^{0}C is passed through one half of the cell on one side of the film. On the other side of the cell a swep stream of CO_2 free air at a similar humidity and temperature is passed. The amount of CO_2 in the swep stream passing over the film is collected and measured.

The carbonation test was carried out at a carbon dioxide concentration of 5% (± 0.2%) in an environment of 65% (± 1%) relative humidity and 20^{0}C (± 1 ^{0}C). The depth of carbonation was measured at the start of the test and thereafter each week up to 3 weeks' exposure in the chamber. At these times, four cores from each mix were removed from the chamber and the depth of carbonation was determined by splitting the core longitudinally and spraying the split surface with a 1% phenolphthalein indicator solution. After 24 hours the depth of carbonation was measured at three locations at right angles to the exposed surface to an accuracy of 0.5 mm in accordance with RILEM recommendations in report CPC-18 (RILEM, 1988). An average of the three readings from the four cores was reported as the depth of carbonation after each week's exposure in the chamber. These values were plotted against squre root of the duration of exposure and the rate of carbonation was determined for each mix. The rate of carbonation of normal Portland cement concrete is primarily influenced by the water-cement ratio and other factors have only a marginal effect.

Taywood Engineering Ltd/Brunell University measures CO_2 and O_2 diffusion characteristics on some proprietary treatment systems, using a method similar in principle to that used by the PRA. The surface treatment is laid down on an unglazed, porous, ceramic plate 5 mm thick and conditioned at 60 % RH and 24^0C for at least 8 weeks before testing. O_2 containing 15 % CO_2 is passed at known pressure and flow rate over the coated face of the plate, while a helium stream is passed over the other face. The helium gas stream is monitored by gas chromatography and analyzed for CO_2 and O_2.

In CEN tests for the depth of the carbonation, variations in environmental control and concrete production techniques were heavily influencing the carbonation readings. Only one laboratory conformed to the environmental requirements of a temperature of 20 ± 2□C, relative humidity of 65 ± 5% and an atmospheric CO_2 concentration of 350 ± 50 ppm. Method of measuring depth of carbonation is 50mm slice broken from prism and phenolphthalein sprayed on freshly broken surface. Measurement made by taking the average of 5 readings made on each face. Average carbonation depths from the two specimens to be reported for each exposure class.

4.3 The Test Methods of the Cl Penetration

The resistance to chloride-induced corrosion largely controls the durability performance of the rendering in coastal and marine environment. There are a number of approaches to quantify the chloride penetration resistance of the rendering. They include the determination of chloride penetration after exposure in a chloride solution or seawater.

The most commonly used methods of assessment are [11]:

□□determination of *chloride front* with silver nitrate indicator,

□□*chloride penetration profile* from analysis of chloride ions of samples taken at different depths from the exposed surface, and

□□migration tests involving the measurement of chloride level of the solution in the receiving chamber opposite the source chamber.

The silver nitrate indicator appears to be the simplest method for determination of the depth of chloride penetration into the rendering. It has been reported by Otsuki et al. (1992) that by spraying a 0.1 N AgNO3 solution on freshly broken rendering sample, the presence of chloride, from a minimum concentration at 0.15% by mass of cement, can be detected by the change in the color of the spayed surface.

Determination of chloride profile is possibly the most popular tool used to assess the chloride resistance of rendering both qualitatively and quantitatively. In qualitative terms, comparisons are made after a similar exposure period of various rendering samples. If it is assumed that diffusion is the main transportation mechanism of chloride into the rendering. Then according to Fick's second law, a diffusion coefficient can be calculated by fitting an error function to the measured chloride profile. It must be noted however that a chloride diffusion coefficient, determined from a measured chloride profile, is not unique in value. It can vary significantly with the periods of exposure [12].

Accelerated electrical techniques such as the measurement of total charge passed according to ASTM C 1202 have also been used, as well.
Most chloride diffusion coefficient test methods fall into three basic categories:

1. Chloride flux procedures determine the diffusion coefficient by measuring the flow of chloride through a known area of concrete over time (flux). The driving force in this test is simply a concentration gradient across the sample. The diffusion coefficient is calculated from the rate of change in the chloride concentration in the sodium hydroxide reservoir.

2. Chloride migration procedures reduce the test duration by driving the chloride through concrete with an electrical potential. The diffusion coefficient calculation varies between the two migration methods typically used; one method is based on the conductivity of chloride-saturated concrete, and the other is similar to the chloride flux test with corrections for the electrical current.

3. Chloride ponding tests also have two versions; one is known as static ponding, and the other is known as bulk diffusion. Increasing the solution concentration, the ambient temperature, or both accelerates these procedures. In one procedure, a concrete specimen is ponded with a chloride solution, while in the other method the specimen is immersed in the chloride solution. After a certain time period, the chloride content data are mathematically fit to Fick's second law of diffusion as a function of depth to obtain the apparent surface concentration and diffusion coefficient. The flux and migration test methods presented produce similar values for the effective chloride diffusion coefficient for concrete.

The tests of Cl ingress by State Highway Authorities, Transportation Research Board; USA are carried out on 100 mm concrete cubes which after curing are treated and immersed in a 15% NaCl solution for up to 21 days. They are then air dried for 24 days. The weights of the cubes are recorded at various intervals during the curing, soaking and drying periods and the cube is split in half, crushed and the Cl ion content is determined.

The diffusion time of the Cl ions through the rendering could be considered the initiation period. The diffusion coefficient is the parameter that describes the phenomenon and it could be measured on sample extract from the building members. Similar to carbonation, the end of the propagation period for chloride attack could be the moment when acertain percentage of the reinforcement cross section is damaged [12].

4.4 SO_2 and SO_3 effects

Because SO_2 gradually attacks the substrate through thin successive layers spalling, the initiation period for the substrate cross sections could be considered the time to damage of the rendering. Quantifying the effect of SO_2 is important for determining the performance of the renderings.

For the SO_2 attacks, wear rating measurements are made on the struck face and the opposite face of the cubes. On each of these faces 2 diagonal measurements are made of the distance from the edge of one corner damage to the edge of the diagonal opposite corner damage is calculated as the sum of loss in mm of the four measured diagonals divided by 8 or the average depth of erosion and damage for one corner [13].

The simulation experiments are carried out in a flow chamber of controlled temperature, relative humidity and SO_2 concentration. The specimens are exposed for a period of 6 and 12 months in air 0.3 ppm SO_2 as pollutant and 0.501 min^{-1} flow gas velocity at 25^{0}C temperature and 95% relative humidity. To ensure that the sulphation reactions would occur only on the esxposed surface of the samples, a passivation treatment is applied to the samples by means of a graphite paint on the non-exposed faces. After 6 and 12 months, the samples are removed from the simulation chamber and the samples are cleaned in order to remove the passivating graphite paint and then the samples are preserved in an inert atmosphere. The pore structure identification, the determination of SO_2 effects and mineralogical investigations are carried out by the mercury intrusion porosimeter (MIP), specific surface (BET), ion chromatography (IC), X-ray diffraction (XRD), infrared spectroscopy (FTIR), thermal analyses (DTA-TGA) and electron microscopy (SEM-EDX and TEM). The results reveal that the total porosity of the building material decreases after 12 months.

In the tests of determining the SO_3 effect, the treatment is held above a solution containing 6 % SO_3 in 28 days. After 28 days, the effects are observed [14].

4.5 Water and water vapor transmission and penetration test methods

The permeability of the renderings to the water and vapor is the most problem in the building engineering so there are tests for the permeability of the building materials. When measuring the water permeability of the rendering, a sample with length l, is put in a cylindrical container whose tips are open. From one tip, water is applied with the pressure P. at the other tip the amount of the water passed through the rendering per time is measured. If the water permeability coefficient of the rendering is 10^{-9}-10^{-10}, the rendering is non-permeable.

In capillary water absorption test, firstly the dry weight of the sample of the rendering is measured. The sample is put on the surface of the water. With the determined time intervals, the weight of the sample is measured then the amount of the absorbed water.

The ASTM E514 test procedure is developed for laboratory testing to evaluate water penetration and leakage through masonry. Several modifications to the standardized test chamber and procedures are undertaken to accommodate all of the proposed tests and to permit weathering to simulate field conditions. In order to accelerate the tests, interchangeable spray is built for simultaneous testing of up to 3 samples. As specified by the test procedure, testing is carried out continuously for a four-hour period [8].

For water penetration, RILEM CP 11.3 specifies the method for determining the absorption of hardened concrete by immersion in water after having been in a vacuum of 100-250 N/m^2 for 24 hours. BS 4315 describes a test which simulates the conditions of the wall of a building under suction forces and driving rain. (Suitable for building components)

For the tests of the water permeability of the materials, the cells of various specifications and dimensions have been employed in order to admit fluid under pressure to one side of the specimen and measure the flow either at the inlet or at the outlet.

Water vapor permeability of the renderings is determined with a simple experiment. Dry $CaCl_2$ is put in the cylindrical container in order to absorb water vapor as a hygroscopic material. The sample is settled to the mouth of the cylindrical container as a tap and the intersection is covered with the paraphine. The weight is measured then it is put in a board which has constant temperature and vapor pressure. As $CaCl_2$ absorbs water vapor, the vapor pressure is zero in the container. The container is weighed at the determined time intervals in order to obtain the amount of the absorbed vapor.

Water vapor transmission is tested by 2 methods. In wet cup method, the sample on a suitable substrate seals with the sample. The sample and cup are placed in a cabinet with a controlled atmosphere. The weight loss of the sealed cup is measured at various intervals, giving the rate of evaporation through the sample. In dry cup method, thge sealed cup contains a desiccant. the sample and cup are placed in a humidity cabinet and the weight is measured like the wet cup method [8].

There are two different types of water vapor diffusion tests, as well (Water vapor transmission test and water vapor diffusion tests). In the water vapor transmission test, the water vapor passing through the specimen is collected either by condensing it or by absorbing it with a desiccant. In water vapor transpiration test, the loss of weight of a saturated specimen due to the evaporation of water is measured and transport parameters may be deduced from the drying curve [15].

The absorption of the materials has 2 basic parameters; one of them is the mass of water which is required to saturate the material (effective porosity) and the other one is the rate of penetration of the capillary rise (the absorptivity). The tests of the absorption are surface absorptivity test carrying out on the surface and in the drilled hole absorptivity test, a hole is drilled and water is admitted through it.

As a cause of the water permeability through the renderings, the freeze-thaw is important to be investigated. In freeze-thaw tests, firstly all pores of the sample are filled with water. The temperature of the sample is 22^0C and it is put in a board whose temperature is – 20^0C and it is waited for a determined time. After that time, it is taken out and put into water whose temperature is 20^0C. This experiment is repeated 25 times. At the end of the experiment, there is no loss of the mass, there are no cracks on the surface and the compressive strength does not increase by % 80. The decrease at the corners is observed at the weak renderings after 6 or 7 cycles. However, the most important factor is the saturation of the rain into the rendering because the freeze-thaw depends on the sufficient amount of water in the renderings [6].

4.6 Test Methods for Acids

When examining the degradation of the renderings by acids, in the experiments the behaviors of the renderings exposed to solutions with different amounts and kinds of acids are observed. The effect on the materials of the renderings is also examined because with the help of the behaviors of the materials to the effects of the acids, it is possible to obtain high performance renderings. At the end of the experiments, for the high performance of the renderings it is necessary to understand whether the loss of the dimension of the renderings is or not.

4.7 Salts Crystallization Tests (RILEM 127 MS TC 1998)

The sample is placed in glass or Plexiglas which is filled up to 20 mm from bottom with a sodium sulphate solution with a concentration of 10 % (m/m) anhydrous salt dissolved in pure water. After 24 hours, the sample is taken out of the container which is emptied, cleaned and partly with clean and dry gravel (grain size 2 to 4mm) and the sample is replaced on top of the gravel. The spaces around the sample is closed by hard polystyrene foam strips so that only the upper face of the specimen is exposed to the environment. The container is placed in a climatic chamber of 20^0C and 50 % RH and weighed until constant mass. Before testing, a first profile of the upper surface of the sample is defined along chosen lines is read and drawn with the use of the laser sensor. The damage of the surface is measured by calculating the difference between the vertical coordinates of two or more subsequent profiles and determine whether if the salt crystallization causes decay [16].

CONCLUSION

The rendering is the essential part of the exterior section of the buildings. It supplies good connection between the façade materials and the structural wall. Sometimes, the rendering becomes the façade material of the building. That's why it should be durable to the environmental conditions. There are different degradation factors that affecting the properties of the rendering such as UV light, acids, salts or biological effects. For the good performance of the rendering, the experimental investigation should be done to determine the durability of the rendering against atmospheric conditions. Within the help of the durability tests, high performance renderings or exterior coverings should be determined and used in the construction. This paper should be a guide for the determination of the durability properties of the renderings and the exterior coverings. Therefore, aesthetic, durable and high performance of the exterior coverings should be applied in the architectural design.

References

[1] Sandin, K., (1995), "Mortars for Masonry and Rendering Choice and Application", Building Issues, volume 7,3.

[2] Karaguler, M.E, (2003), "The Renderings", Turkish Ready-Mix Concrete Unity, Istanbul.

[3] Diri, C., (2003), "The Behaviors of the Ready-Made Renderings with The Synthetic Binder to The Environmental Factors: A Research", MSGSU, PhD Thesis, Istanbul.

[4] Mavi, O., (2000) "Kireç Harç ve Sıvaların Fiziksel ve Mekanik Özelliklerinin İyileştirilmesi", Graduate Thesis, Istanbul Technical University, Istanbul.

[5] Jones. M., (2002) "Effects of UV Radiation on Building Materials" UV Workshop, New Zealand.

[6] Haagenrud, E.S., (1997) "Environmental Characterization Including Equipment for Monitoring," CIB W80/RILEM 140-PSL Sub Group 2 Report.

[7] British Standard 5262 (1991), "Code of Practice for External Renderings"

[8] Leeming, M. B., O'Brien, T. P. (2005) "Protection of Reinforced Concrete by Surface Treatment", CIRIA, London.

[9] Downer, H.W. & Beddoe. R.E., (2002) "Prognosis of Concrete Corrosion Due to Acid Attacks" 9DBMC Durability of Building Materials and Components, Brisbane, Australia.

[10] Chown G.A., (1999) "Requirements for durability and on-going performance in Canada's objective based construction codes" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.

[11] Sirivivatnanon.V., & Khatri.R.P., (1999) "Characterising Cl penetration resistance of concrete" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.

[12] Miltenberger, M.A., J.J. Luciano., Miller.B.D., (1999) "Comparison of Cl Coefficient Tests for Concrete" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.

[13] Halliwell. M.A., & Crammand. N.J., (1999) "Avoiding the Thaumasite Form of Sulfate Attack" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.

[14]Sabbioni.C.,Zappia.G.,Riontino.C.,BlancoVarela.M.T.,Aguilera.J.,Puertas.F.,Palomo.A., Van Balen.K.,Toumbakari.E.E., (1999) "SO_2 environment degradation of synthetic pastes of Portland cement" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.

[15] Bashaer.L., Kropp., J., Cleleand. J.D., (2001) "Assessment of the durability of concrete from its permeation properties: A review," Construction Building Materials, Vol.15(2-3), pp.93-103.

[16] Binda.L., Garavaglia.E., Molina.C., (1999) "Physical and mathematical modeling of masonry deterioration due to the salt crystallization" 8DBMC Durability of Building Materials and Components, Vancouver, Canada.