

# Reduction of Air nitrogen oxide by cement composites facade containing nanomaterials

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## ABSTRACT

Nitrogen oxides are released in the combustion process of fossil fuels and when combined with some volatile organic compounds in the air, they create dangerous soot in cities. Health experts always warn that exposure to a high concentration of nitrogen oxides causes very dangerous and acute respiratory problems for citizens. The use of nano zinc oxide in concrete to absorb this pollutant in the air reduces the dirtiness of the surfaces and the amount of pollutant in the air. 6 samples each with 3 nitrogen oxide absorption brings the number of statistical population to 18. To perform these tests, UV tests were taken from the samples. This test will be done according to ASTM C642 method. The addition of the highest percentage of zinc oxide compared to other percentages (5%) and 3% nanosilica results in greater density and the highest percentage of nitrogen oxide absorption up to 8.6% of the original sample. As a result, adding a higher percentage of zinc oxide up to 5% and nanosilica up to 3% will be effective in reducing and absorbing about 8.6% of nitrogen dioxide in the air, which can be used in environmental concrete for sustainable development.

## 1. Introduction

Nanotechnology is not only a technology for creating special spaces, but also seeks to find a

way to create an optimal building. Based on the principles of sustainability, every building should be designed in such a way as to

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minimize the use of new resources and at the end of its useful life, create a resource for creating other structures, while most of the resources in the world are used to create environments. Artifacts have been used, repairing and improving the condition of current buildings to reduce the effects of destroying the environment has the same importance as creating new structures, which can be developed in the use of recycled materials. . When the access to new resources is minimized, solutions are proposed with which buildings with one use can be converted into multi-functional buildings; But some necessary changes can become the main form of the structure or building. Such as nanotech, which can be included by changing the materials, changing the use and thus changing the space, or nano coatings and nano robots, which are the simplest results of nano science, can understand their surroundings or show that reaction; Materials that undergo changes due to movements caused by earthquakes or possible stresses; Or sensors that are getting smaller day by day and nanocomposites that have the ability to repair themselves. Reconstruction and modification of materials at the atomic level is locally one of the important engineering issues that laser advances and atomic nanotubes have been developed in line with this goal to force the atom to go back and spend less energy in the positions. Be right on your own. It is even possible to use nanoparticles in the form of nanoparticles (nano patches) to fill them inside. Also, with the construction of new materials in the field of construction technology, we will have structures that, by changing the arrangement of atoms in the nano scale, phenomena such as acid rain, air temperature, and chemical mechanisms during execution and construction will no longer be destructive factors. And the limiter will not be discussed [1].

The direct and substantiated proof of the direct interaction of nanotechnology with architecture are materials (physical products) that generally give different uses to buildings. Such materials create new possibilities for completing and improving the architectural object and thinking about a new form of life [2].

In 1660 AD, John Olin raised the issue that the polluted air of the city of London causes the color change and depreciation of the facade stone of the buildings. At the end of the 18th and 19th centuries, painters and writers dramatically illuminated the soot-filled and polluted urban areas in their works and

presented the harmful effects of atmospheric pollution in an interesting way. Recently, efforts have been made to systematically and scientifically study the characteristics of atmospheric pollution and their effects on buildings [3].

Atmospheric pollution means that the characteristics of the air atmosphere change under the influence of human efforts. The efficiency of the natural or polluted atmosphere varies from place to place and in different periods of time. For example, coastal areas usually have more salt in the atmosphere, but dry areas do not. Compounds such as carbon dioxide, sulfuric acid, nitrogen oxides and particles such as soot are among the atmospheric pollutants that have destructive effects on stone facades. Carbon dioxide, which is a well-known greenhouse gas and the cause of global warming, can combine with water in the atmosphere and form carbonic acid, which means that normal precipitation is a weak solution of carbonic acid with a pH It is about 5.6 (for your information, pH equal to 7 is neutral and zero pH gives the maximum amount of acidic property) and if the amount of carbon dioxide in the air increases too much, the amount of acidity of rainfall will not increase significantly. It is the reflection of other pollutants suspended in the air such as sulfur dioxide and nitrogen oxides, which causes more acid rains, so that sulfur dioxide reacts with water in the atmosphere and sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) establishes; A process known as (acid rain). Despite this pollutant, the acidity level can increase to 4.5 or even 3.5. Nitrogen oxides suspended in the air also create such acidity by creating nitric acid. The mentioned polluted gases are created as a sign of industrial, commercial and residential activities in urban areas, and recently in rural areas. Carbon dioxide is a by-product of many industrial activities and movements, and is evenly distributed in the British atmosphere. Rains containing sulfuric acid are caused by the activity of power plants and are common in areas where coal is used for heating. By the 1950s, the use of coal for domestic heating had created a thick layer of soot in London's skies. that this type of pollution has had many devastating effects on British stone buildings [3].

Pollutants such as carbon dioxide also affect the climate of the region. It is predicted that by the next 50 years, we will have a temperature increase of 2 to 5 degrees Celsius and the sea level will also increase; Of course, the mentioned figures are averages and there may

be different figures in different regions. It is likely that the southern part of the UK will experience longer periods of drought and reduced seasonal rainfall. Human-made pollution will cause more droughts and storms. Such changes will cause the erosion of buildings as well, but the amount of detail cannot be predicted. For example, the duration and intensity of rainfall may increase due to high wind speed and storminess. At the same time, rainwater may penetrate the stone more. The amount and direction of movement of flowing water due to rainfall will also change. An increase in rainfall will cause water to flow in areas that have not had a history of heavy rainfall, and the large volume of sulfates suspended in the air will turn into sulfuric acid as a sign of pollution with the formation of rain, which will increase the penetration of rain into the rock and The processing of salt solutions and their accumulation in the middle of the stone. When salt solutions are formed, they flow to other places and after drying, salt crystals are formed. The pores can be inserted and the stone can be crushed. Therefore, with the formation of salt crystals, the rate of rock weathering also increases. The amount of weathering, in addition to air pollution, also depends on the ingredients of the rock and weathering records [3].

The prosperity of the population and the process of urbanization has brought an influx of all kinds of pollutants and dangerous toxic substances to the city dwellers all over the world, and therefore scientists are always looking for new solutions - from the invention to the production of catalytic converters to the application Substitute fuels have been used to reduce the emission of pollutants - along with creating better conditions for the lives of communities living in big cities. Swedish and Finnish scientists have introduced the latest invention of the world of architecture to the world. Engineers and researchers of Skansa company, whose headquarters is located in Stockholm, the capital of Sweden, have conducted their recent research activity as part of a Swedish-Finnish project worth one million seven hundred thousand dollars. This project was designed and implemented in order to produce catalytic cement and new concrete compounds with titanium oxide coating for covering and facade of buildings. Titanium oxide is a special chemical compound that is often used in white paints and toothpaste. According to chemists, this substance has unique properties and characteristics, so that when exposed to the ultraviolet rays of the sun,

it becomes a highly active and reactive substance. Swedish researchers state that this characteristic of titanium dioxide causes ultraviolet rays to cause a catalytic reaction, which results in the destruction of molecules of various pollutants, including nitrogen oxides. It should be mentioned that nitrogen oxides are released in the process of burning fossil fuels and when combined with some volatile organic compounds in the air, they create dangerous soot in cities. Health experts always warn that exposure to a high concentration of nitrogen oxides causes very dangerous and acute respiratory problems for citizens, although studies have shown that these pollutants can easily and with a rain fall. They are removed from the air. This report adds: The catalytic reaction created in the new building materials has other important properties, so that the reactivity and intense chemical activity of these materials in the vicinity of ultraviolet rays can prevent the adhesion of bacteria and dirt. It prevents on the walls and buildings and causes these pollutions to be easily washed off the walls by a rain.

The by-products formed after the occurrence of this chemical reaction, which is called photocatalysis, are safe. In fact, the type of by-products created during this reaction depends on the type of compounds that enter and participate in the reaction, so that the carbon-containing molecules of the organic compounds involved in this reaction turn into carbon dioxide and They turn into water, while nitrate salts will remain from the molecules of various nitrogen oxides.

For example, we can see stone sculptures in Italy at risk of erosion and air pollution [3] as shown in Figure (1).



**Figure 1. Stone sculptures in Italy at risk of erosion and air pollution [3].**

Nanosilica can reduce cement consumption, improve concrete quality and increase its efficiency [4, 5].

The incorporation of TiO<sub>2</sub> into cementitious composites has been investigated by some researchers. Sanaf et al. (2012) added fractions of different volumes of Nanosilica and Nano TiO<sub>2</sub> to the mortar mixture and evaluated the hardened properties. It has been reported that when the content of nanosilica and TiO<sub>2</sub> is low, mechanical strength is not significantly affected, but with increasing weight percentage of nanosilica and TiO<sub>2</sub>, mechanical strength increases by 3% and 12%, respectively [6].

In a study, the effect of using nanosilica (NS) and microsilica mixtures on the mechanical properties of ultra-high performance cementitious composites (UHPCs) is presented.

To do this, two concrete groups with and without silica fume with a ratio of water to fixed cement and fixed cement were designed. Commercial NS used in partial replacement of cement with weight of zero percent, 0.5 percent, one percent, two percent and 3 percent. The results show that among the different contents of NS, UHPC containing 2% NS showed the best results in compressive strength, tensile strength, modulus of elasticity, flexural strength, load handling behavior and rupture energy in 90 days. UHPC samples containing cementitious materials (NS and SF) gave better results than concretes containing only NS. In addition, the effect of 1% NS is approximately equal to 10% SF [7].

In one study, the photocatalytic activity of TiO<sub>2</sub>-coated self-compacting glass-containing mortars (SCGMs) was investigated in terms of removing air pollutants and inactivating bacteria. TiO<sub>2</sub>-impregnated glasses were used as controls to compare performance [8].

Nitric oxide (NO) and Escherichia coli K12 were used as air pollutants and bacterial pollutants, respectively. In addition, the weathering resistance of TiO<sub>2</sub> coated samples was investigated. Regarding NO removal, it is clear that no significant difference was observed between TiO<sub>2</sub> and SCGM impregnated glass, and both showed high NO removal efficiency when using conditions 1 (C1, without weathering) (for EtOH mortar, Up to 14.33 mg per square meter H1).

However, after a period of abrasive weathering, condition 3 (C3, abrasive process), the ability to remove NO from TiO<sub>2</sub>-impregnated glass samples almost disappeared. In contrast, the ability to remove NO from SCOM with TiO<sub>2</sub> coating remains high performance (for EtOH mortar, 8.75 mg / m<sup>2</sup> H1). The porosity of the SCGM surface

with the coating appears to help maintain the desired TiO<sub>2</sub> particles after abrasion. For antibacterial activity, a general inactive action of E. coli removal was observed in TiO<sub>2</sub>-impregnated glass and SCGM samples within 60 min of UV irradiation.

After the wear process (C3), the inactivation of E. coli in TiO<sub>2</sub>-impregnated glass is almost negligible, whereas, the concentration of E. coli remaining on the surface of TiO<sub>2</sub>-coated SCGM is only about 10<sup>5</sup> to 10<sup>3</sup> CFU / ml. Dropped. The results indicate that TiO<sub>2</sub> is retained in the porosity of the coated SCGM and can still play a role in inactivating E. coli. Considering all the results, it can be concluded that inactivation of photocatalytic bacteria is a more complex process and the results of photocatalytic activity of NO removal can not always be transferred to photocatalytic antibacterial activity. The results of this research are presented in Figure (2) [8].

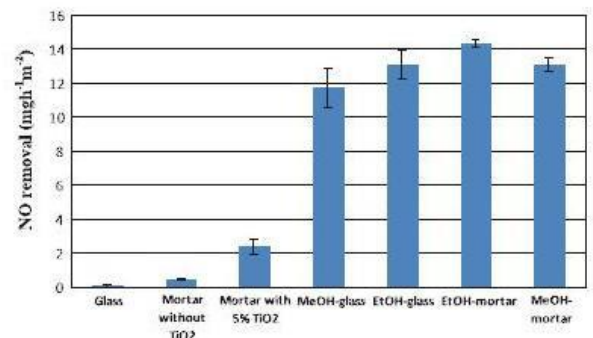


Figure (2) Comparison of NO removal by different samples subjected to UV testing in 60 minutes [8].

In all experiments, a commercial nano TiO<sub>2</sub> powder (P25, Degussa) was available and used as a photocatalyst. The size of TiO<sub>2</sub> was 20-50 nm, BET with a specific surface area of 15 50 50 m<sup>2</sup> / g and ordinary white Portland cement (WC, TAIHEIYO) product of Japanese cement and metakaolin (MK) were used as samples. Recycled glass (RG) from post-beverage glasses was used as a fine material in SCGM. The light green glass bottles are washed and then crushed by a mechanical crusher, followed by a sieve with a particle size of less than 5 mm. Self-compacting glass mortar (SCGM) was prepared by compression of 50 MPa resistance (28 days) using a mixture ratio of 0.8: 0.2: 0.2: 0.4 (WC, MK, RG, water). In order to evaluate the effectiveness of TiO<sub>2</sub> on the photocatalytic activity of mortar, a amount of 5% (cement mass) of nano TiO<sub>2</sub> in the complete mixture was used. The mixing schemes used are given in Table (1) [8].

**Table (1) Mixing schemes used to test water absorption percentage [8].**

Sampels	Status of projects
Mortar without TiO2	Self-compacting glass mortar (SCGM) without TiO2
Mortar with 5% TiO2	Self-compacting glass mortar (SCGM) with 5% TiO2
Glass	Reference glass without TiO2 coating
EtOH-glass	TiO2-impregnated glass suspended in ethanol and glycerol solution at 450 ° C for 120 min
MeOH-glass	TiO2 impregnated glass suspended in methanol solution at 60 ° C for 120 min
EtOH-mortar	Mortar impregnated with TiO2 suspended in ethanol and glycerol solution at 120 ° C for 120 min
MeOH-mortar	Mortar impregnated with TiO2 suspended in methanol solution at 60 ° C for 120 minutes

In an article to determine the effect of cement containing titanium dioxide, nanosilica and the presence of waste glass in cement mortar for its potential application in self-cleaning facades.

Studies have shown that waste glass can be a successful alternative to sand, especially when part of it is mixed with sand. In addition, a positive effect of nanomaterials was observed due to self-cleaning and mechanical properties. Visual observation of rhodamine B discoloration on cement mortar surfaces showed that the presence of waste glass did not affect the cleaning properties of titanium-containing commercial cement. The use of waste glass in general can neutralize the negative effect of high nanosilica water demand. Hence, nanosilica can be successfully incorporated and embedded in cementitious composites without the aid of any additional material. The use of nanosilica improves the cohesion between the glass aggregates and the cement due to its paste property and consequent compaction of the cement mortar structure. The use of 3% by weight of nanosilica significantly increases the flexural and compressive strength of specimens containing waste glass materials [9].

The importance of corrosion protection of reinforced concrete in aggressive and corrosive environmental conditions and protection against water absorption has led to the allocation of 150 publications of the Program and Budget Organization entitled Environmental Concrete Structures (translated by ACI 350-89) [10].

## 2. Methods

6 samples each with 3 tests of nitrogen oxide absorption brings the number of statistical population to 18. To perform these tests, UV tests were taken from

the samples. Testing will be done according to ASTM C642 method. Table 1 shows the plans related to the mixture of this study.

In this article, a set of devices were used to measure the concentration of nitrogen monoxide. According to Figure 3, from the left, they are:

- 1- Data logger device or sensor measurement system that can measure nitrogen monoxide gas and record it in its internal memory and then transfer it to the computer.
- 2- The second device is a nitrogen monoxide gas generator. The concentration of nitrogen monoxide can be adjusted. The gas is transferred to the third device by the blue hose.
- 3- The third device has an inlet hose and a free outlet hose. The gas output from the second device is at a constant flow of 3 liters per minute. The gas concentration (PPb) is 2000.

We place a concrete sample with dimensions of 10 x 10 cm and a height of 16 mm in the third machine. The tested plans are according to Table 2. LED lamps shine on the surface of the samples. Inside the body of the third device, sensors for measuring the concentration of nitrogen monoxide were installed. The lamps above the sample are a combination of LED and normal lamps, it includes a wide light spectrum of 50 watts, 25 watts of which is UV and 25 watts of which is the visible spectrum, and we have this radiation on the surface of the sample in a combined form.

The measurement is done in a period of 3 minutes and usually at the same time we reach the stability of the final result for each sample, which results are according to Tables 3,4 and 5.

**Table 2. The Mix designs and Replacement percentage in the tested designs**

Mix designs	Replacement percentage				
	Cement content (kg/m <sup>3</sup> )	Nano Zn	Nanosilica	Water	superplasticizer
1	800	0	0	0.4	0.004
2	800	0.025	0	0.4	0.004
3	800	0.05	0	0.4	0.005
4	800	0	0.03	0.4	0.006
5	800	0.025	0.03	0.4	0.007
6	800	0.05	0.03	0.4	0.007



Figure 3. Device for determining the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs



Figure 4. Device for determining the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs

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Figure 5. The input of nitrogen oxide gas from the tank to the surface of the sample in the test device to determine the reduction of nitrogen oxide adjacent to the samples in the tested designs.



Figure 6. The output and input of nitrogen oxide gas from the tank to the surface of the sample in the test device to determine the amount of reduction of nitrogen oxide adjacent to the samples in the tested designs.



Figure 7. Placing the concrete sample in the device to carry out the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.

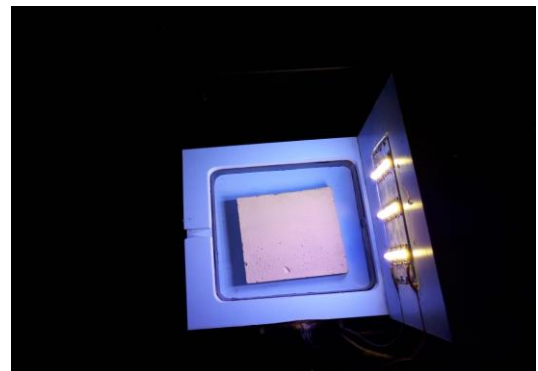


Figure 8. Radiant light spectrum on the surface of concrete to carry out the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.



Figure 9. Starting the test for the radiant light spectrum on the surface of concrete to perform the photocatalytic activity of concrete to absorb nitrogen oxide gas around the surface of the sample in the test device.

### 3. Results and Discussions

Table 3. The density and amount of nitrogen oxide adjacent to the samples in the tested designs

Mix No.	Density(kg/m3)	Density (kg/m3)	NO Base Conc. (PPb)
1	1901	1896	2005
2	1908	1905	2001
3	1911	1917	2003
4	1925	1933	2004
5	1936	1941	2000
6	1945	1940	1997

Table 4- Nitrogen oxide rate of the samples in the tested plans

Mix No.	NO Base Conc. (PPb)	Output NO Conc. (PPb)		
		Specimen 1	Specimen 2	Specimen 3
1	2005	1896	1888	1889
2	2001	1893	1895	1889
3	2003	1884	1887	1881
4	2004	1759	1762	1765
5	2000	1760	1752	1753
6	1997	1746	1750	1741

Table 5- Nitrogen oxide absorption percentage of the samples in the tested designs

Mix No.	NO Removal (%)	NO Removal (%)	NO Removal (%)
1	5.4	5.8	5.8
2	5.6	5.5	5.8
3	6.0	5.9	6.2
4	12.3	12.1	12.0
5	12.2	12.6	12.6
6	12.9	12.7	13.2

The addition of the highest percentage of zinc oxide compared to other percentages (5%) and 3% nanosilica results in greater density and the highest percentage of nitrogen oxide absorption up to 8.6% of the original sample. As a result, adding a higher percentage of zinc oxide up to 5% and nanosilica up to 3% will be effective in reducing and absorbing about 8.6% of nitrogen dioxide in the air, which can be used in environmental concrete for sustainable development.

### 4. Conclusions

Considering that cement base materials cover a wide range of life and urban communities, it seems that in addition to the function of encapsulating nanoparticles by the cement matrix, it can be used as a potential for removing organic pollution in highways and underpasses with The high wall, which causes the trapping of nitrogen oxide polluting gas resulting from the combustion of fossil fuels, benefited a lot. In this article, 6 designs with 3 nitrogen oxide absorption experiments bring the number of statistical population to 18. To perform these tests, UV tests were taken from the samples. This test was performed according to ASTM C642 method. The results show that by adding nanosilica from designs 4, 5 and 6, compared to the first 3 designs, the percentage of nitrogen oxide absorption does not change much. In schemes 4 to 6, it was observed that the addition of nano-zinc oxide in a constant ratio of nano-silica increases the absorption percentage of nitrogen oxide.

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