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A Review on Air Pollution Reduction Properties of Concrete by using Supplementary Cementitious Materials

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Abstract- In current world scenario global warming and greenhouse gas effect is ever-increasing and very concerning problems for humanity. In case of air pollution carbon dioxide (CO_2) and oxides of the nitrogen (NOx) are two of the major pollutants which contributes in enhancing the pollution concerns. Every action of the people now needs to be in synchronization with the perspective of countering these vital problems and adopting the measures of minimizing the effect of the rising problem. From the engineering perspective concrete is crucial product which is used in construction sector for development activities of the nation across the world, which makes concrete the second most utilized product after water. If one can implement the pollution reduction concept in the pivotal product like concrete the impact and application of the concept can reach to wider population. The use of supplementary cementitious material (SCM) in the concrete can give the positive outcomes for battling with air pollution problems. The concept such as photocatalytic concrete and CO_2 reducing concrete can be introduced in the construction sector. SCMs like Titanium Dioxide, Zeolite, Zinc oxide etc. shows positive outcomes for pollution reduction phenomenon. In this paper multiple literature has been studied for analyzing the role of SCMs in concrete are its pollution reduction aspects in terms of air pollution.

Keywords: Air pollution, Air Pollution Reduction, Carbon Dioxide ($CO_{2,}$), Concrete, Compressive Strength Test, Direct Air Capture, Photocatalytic, Supplementary Cementitious Materials (SCMs), Titanium Dioxide (TiO_2)

I.INTRODUCTION

Air pollution remains one of the most pressing environmental challenges globally, impacting public health, ecosystems, and climate stability. Among the key pollutants, carbon dioxide (CO_2) and nitrogen oxides (NOx) are significant contributors to smog formation and greenhouse gas emissions, respectively.

Concrete, a ubiquitous building material, is responsible for a substantial portion of the industry's carbon footprint. However, the integration of SCMs into concrete production offers a promising avenue to reduce environmental impacts. These materials, such as fly ash, slag, and zeolites, Titanium Dioxide are known not only to improve the mechanical properties and durability of concrete but also to impart additional environmental benefits. Recent advancements have focused on the use of SCMs to enhance the photocatalytic properties of concrete, enabling it to actively degrade NOx and absorb CO_2 from the atmosphere.

This review paper intends to consolidate current research on the air pollution reduction properties of concrete modified with supplementary cementitious materials. It will evaluate the effectiveness of various SCMs in reducing NOx and CO_2 levels, discuss the mechanisms behind these improvements, and explore the practical implications of integrating these materials into construction practices.

1.1 Supplementary Cementitious Materials

The primary element of concrete, cement, requires a substantial amount of organic matter extracted from natural resources during manufacturing processes, leading to significant CO_2 emissions. Cement can be partially substituted with SCMs to cut down waste and lessen the environmental impact. Additionally, incorporating SCMs helps decrease industrial by products. Under certain conditions, this can reduce the amount of cement needed in concrete. Currently, concrete often includes a mix of silica fume, carbon monoxide, and ground-granulated blast-furnace slag as a primary source for residual gypsum [1].

1.2 Benefits and implementation of using SCMs:

Following are the various benefits of using SCMs in concrete.

a) Increasing in sustained durability but can obtain solidness more slowly (Irregularity in silica smoke; it gains strength quickly).

b) Increasing longevity by making less penetrable.
c) Reduces the chance of in breaking at bottom peak hydration temperatures.
d) Delays set time by slowing the rate of hydration.
e) Reduces the amount of C-S-H reaction product.
f) This will lower the chance of oxychloride development, the origin of early joints found in some mid-western pavements.
g) Mitigates alkali-silicates reactivity.

II. IMPORTANT CONCEPTES IN DEPOLLUTING CONCRETE

2.1 Photocatalytic Concrete

Photocatalytic concrete is concrete that contains photo catalysts, typically titanium dioxide (TiO_2). These photocatalysts are activated by light, usually ultraviolet (UV) light, which enables the concrete to break down pollutants in the air through a process known as photo catalysis. A catalyst is a substance that speeds up a reaction and increases the rate of a chemical reaction without being consumed in the process. Photocatalysis is specifically driven by light. This method is a type of Advanced Oxidation Technology that can be used to purify water and air. As illustrated, this technique uses solid semiconductor catalysts, typically TiO_2, which are activated by UV light of a specific wavelength. Figure 1 shows the photocatalytic reaction of TiO_2 on an exposed surface for reducing NOx.

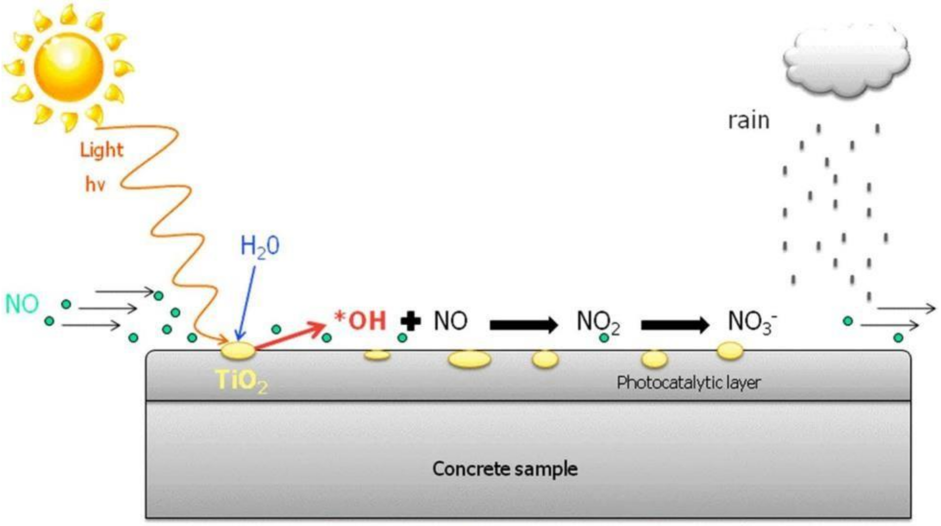

Fig 1. Photocatalytic chemical reaction of TiO_2 with exposed surface

2.2 Titanium Dioxide (TiO2) Powder

Titanium powder is a finely divided form of titanium, a strong, lightweight, and corrosion-resistant metal. It's used in a variety of applications, particularly where the properties of titanium such as high strength-to-weight ratio, biocompatibility, and resistance to corrosion. Titanium is found in all living things and soils on Earth, and makes up about 0.44% of the Earth's crust. The most common ores of titanium are rutile and ilmenite.

Fig 2: Titanium Powder

2.2.1 Properties of Titanium Dioxide (TiO_2)

The properties of Titanium dioxide are as follows:

- Corrosion Resistance
- Biocompatibility

- Good Ductility
- High Melting Point
- Non-Magnetic

2.3 Chemical reactions in Titanium -based concrete

Nitrogen oxides (NOx) significantly contribute to air pollution, creating environmental risks on their own and reacting with atmospheric oxygen to produce ozone, a key element of smog. Laurent Barcelo's research highlights that titanium dioxide acts as a photocatalyst without being depleted, enabling its continuous use without frequent replacement. The complete removal of NOx involves a multi-step process, as outlined in the following equations:

$NO + 2OH \rightarrow NO_2 + H_2O$.

This process by itself does not eliminate nitrogen oxides but instead transforms nitrogen monoxide into another harmful compound, nitrogen dioxide, enabling a subsequent reaction to take place:

$NO_2 + OH \rightarrow NO_3^- + H^+$.

The reaction ultimately eliminates the remaining nitrogen dioxide, converting it into nitrate ions, which then react with ionized hydrogen to form nitric acid (HNO_3). In this heterogeneous photocatalytic oxidation process, NOx are oxidized into water-soluble nitrates that can be washed away by rain [36].

2.3 Carbon Dioxide Reducing Concrete

CO_2-reducing concrete, also known as carbon-reducing concrete or carbon capture concrete is a type of concrete engineered to minimize the carbon emissions typically generated during traditional concrete manufacturing and usage. The primary goal is to mitigate the substantial CO_2 emissions typically generated during the manufacturing of cement, which is a key component of concrete.

2.4 Zeolite

Zeolites are framework silicates characterized by a tetrahedral structure, where each tetrahedron consists of an oxygen atom surrounding a central cat ion (usually Si^{4+} or Al^{3+}). The structure forms open channels and cages, which are filled with HO and various exchangeable ions like potassium. These channels are large enough to accommodate guest species. Within the moistening phases, insufficiency arises at a temperature of 400°C Reversible zeolites are mostly below 400°C permeable, hydrated alumino silicate. They can be natural minerals [2].

Fig 3: Zeolite Powder

2.4.1 Properties of zeolite

The following properties of zeolite are:

- High-rise level of hydration
- Small volume, big nullified density.
- Stability of the precious stone structure when dried out.
- Cat ion trade properties
- Mechanism effects

2.5 *Chemical reactions in zeolite-based concrete*

Calcium silicate hydrates generated through hydration reactions among calcium silicates plus water were used to compose most of all concrete utilized for concrete structures [35].

The response spoken to:

- 2 C2S + 7 H2O → C3SH4 + 3Ca(OH)2
- 2 C2S + 5 H2O → C3S2H4 + Ca(OH)2

Throughout worn and revocation, ingredients like hydrated lime and calcium proceed escorted by CO_2 acid by produced aragonite. The reaction occurs as:

- $Ca(OH)2+ CO2 \rightarrow CaCO3 + H2O$

Carbon acid gas reproduction and storage (DAC) can be reached across these reactions, involved in :

- $C3S2H4 + 3\ CO2 \rightarrow 3CaCO3 + 2\ SiO2 + 4\ H2O$

Utilizing these reactions provides opportunities for Direct Air Capture, and presents justifiable and environmental protection.

III. LITERATURE REVIEW

The following literature review represents the use of SCMs in the concrete and its outcomes:

C.S. Poon et al. (2006) The study evaluated the effectiveness of incorporating air cleaning agents into the production of concrete paving blocks using local waste materials to remove nitrous oxide (NO). Three types of TiO_2 were compared in the study. The results indicated that the photo degradation of NO is influenced by the porosity of the blocks, with higher porosity leading to greater NO removal capability. Additionally, P-25 TiO_2 was found to have the best photocatalytic ability when compared to anatase and rutile forms sourced from an industrial source. However, the rutile form was particularly appealing due to its lower cost compared to P-25 [2].

Babak Ahmadi et al. (2010) has find the effectiveness of a locally produced pozzolanic admixture in enhancing the mechanical and strength characteristics of concrete is evaluated and contrasted with other pozzolanic admixtures. The experiments were divided into three sections: in the first, a thermos gravimetric method was used to assess the pozzolanic reactivity of silica rage and distinctive zeolite. The results in this instance showed that the features of zeolite were not. Although it seemed to have a considerable pozzolanic reactivity, it was as responsive as silica fume. In the subsequent section, varying amounts of silica sand and zeolite were used in place of cement in concrete. A few physical and solidity tests of concrete were conducted, along with blends. Considering these findings, productions comprising concretes that are composed of a special zeolite component advanced and indeed were equivalent [3].

Heather Dylla et al. (2011) studied and assessed the environmental efficiency of TiO_2 coating in the photodegradation of mixed NO_2 and NO gases from the atmosphere decreases with higher flow rates and an increased NO_2/NO_x ratio. The highest photo breakdown rate was noted at 25% relative humidity, which ideally balances the presence of hydroxyl radicals on the surface with NOx interaction with the photocatalytic surface [4].

Meysam Najimi et al. (2012) have studied the approach for incorporating common complexation in SCMs has been explored. The study compared the properties and durability of concrete made with 15% and 30% of natural zeolite to unmodified natural zeolite rock. The results revealed that natural zeolite significantly improves water infiltration, chloride ion penetration, and drying shrinkage of concrete; however, its performance was not observed in acidic environments. From a practical perspective, a 15% natural zeolite blend was deemed an effective choice for enhancing the durability of concrete [5].

B.Uzal et al. (2012) the properties and characteristics of cement paste were examined by analyzing the microstructure of blended cements primarily composed of minerals, incorporating 55% by weight of zeolite tuff. Additionally, dispersants and improvements in compressive strength were established [6].

N. K. Amudhavalli et al. (2012) has considered an impact with mica range of quality, and quality of plaster and watched the silicon dioxide smolder have more prominent fitness than cement and a more note-worthy surface zone. So the consistency increments enormously, when the silica rate increments regular consistency enhances by approximately 40% when using silica seethe rate increases between zero percent in addition 20 percents. The optimal situation is seven and twenty-eight-day compression resistance and flexural capacity achieved between ten and fifteen % at the sand vapor substitution stage [7].

Marwa Hassan et al. (2013) has researched several advantages of incorporation of TiO_2 into asphalt pavements by the photocatalytic effectiveness and durability of a water-based spray coating of TiO_2 in the laboratory. Incorporated as a surface spray coating, TiO_2 effectively eliminated NOx pollutants from the air stream, achieving an efficiency of 31–55% in laboratory settings. The peak NOx removal efficiency was attained with a coverage rate of 0.05 L/m2, alongside an SO_2 reduction efficiency of 19.8%. The NOx reduction efficiency is influenced by the pollutant flow rate, relative humidity, and UV light intensity [8].

SS lucas et al. (2013) has performed NOx reduction test on cement mortar cubes. The author has made various cubes using only Cement, only gypsum, only lime, and combination of two cementitious material. In total 5 mix designs were prepared. The author has performed the porosity, strength, and NOx degradation test on all the developed mortar mixes. Among all the mixes the TiO_2 powder was added at 0.5, 1.0, 2.5, and 5.0% with replacement of individual cementitious material. Among all the mortar mixes the mortar mix with the cement only ©, tends to perform better. The maximum compression strength was found at 1% replacement of TiO_2 in cement mortar which was increased by 5.26%. Also, at 2.5% of TiO_2 replacement with cement shows the maximum percentage of NOx degradation which was about 89% [9].

S. Karapati et al. (2014) performed the experiment by embedding altered and the original P25 photocatalysts in a cement matrix with low percentage loadings (2.5, 1, and 0.5%) were studied. DLS research revealed that the modified titania particles behaved like lipophiles, whereas the original P25 dispersed easily in water. Particles treated with OAOM (P25) exhibited the best dispersion in terms of polydispersity index and particle diameter. The altered titania powders and titania-infused cements demonstrated exceptional photocatalytic activity under both UV and visible light irradiation in NO oxidation, and particularly in NOx elimination. The cements with photocatalysis and modified P25 showed 2–5 times greater NOx removal efficiency compared to those with unmodified P25 [10].

Balraj More et al. (2014) has examined approximately coal dioxide retaining solid pieces watched a lessening on contamination. By trying they utilized pieces of estimated 10x10x10 cm, which can assimilate one mole of carbon dioxide in 50 days. The quality of natrolite does not overlook the quality and solidness. The sort pieces were reasonable and thus utilized regular resolution and it will be ecological [11].

Sabale V.D et al. (2014) has investigated the impact of expansion with asbestos smolder on the substance's Superior Ability: Attributes properties watched that substitution of cement up to 10% with silica smolder results extend in condensed quality, part and flexural quality Above ten percent of practical, which exists in less in compressive quality, malleable quality, and flexural quality at twenty-eight days healing phase. The diminished working capacity refers to substitution amount increments, thus liquid utilization will go up as prices rise substitution [12].

Sudarsana Rao et al. (2014) has considered around blend plan of tall execution concrete utilizing silica rage and super plasticizer and concluded that silica smolder substance increments the comprehensive classification step up to 15% (HPC) the diminishes. Subsequently, the perfect renewal rises 15%. The auto raver rate swapping binder by silicon dioxide smolder increments, the workability diminishes [13].

M. Sedlmajer et al. (2015) has studies present in the present visible contain complexation as a dynamic alloy within the coal which mostly replacement iron-putty. The effect conferred brings information approximately the most impulsive effects and ice zeolite-containing cement's resilience. The building material's qualities of the synthesis aluminosilicate. The stone products are cleaned for 360 days. Efforts to mitigate impact cost using Portland cement's formulation, a structural substance that has provided economic and ecological benefits. Three divisions of total using greatest wheat estimate 16 mm air circulation. The measurement Clinoptilolite comprised 45% vs. 35% of the sieve. Within under fine stage, extended from 7.5 to 30% of the mass of the cement [14].

Magdalena Janus et al. (2015) studied and compared two types of titanium dioxide: unmodified TiO_2 and commercial titania P25. The measurements were carried out in an environment with consistent humidity, temperature, and UV light exposure. The results indicated that the NO oxidation characteristics of concrete materials loaded with N and/or C-modified photocatalysts were much higher. The enhanced NO removal effectiveness of these modified materials was attributed to (i) the increased photocatalytic activity of N and/or C-modified photocatalysts due to the formation of additional energy states in the TiO_2 lattice and (ii) the probable partial reduction of NO to N_2 via the SCR process catalyzed by TiO_2. A novel phase, $CaTiO_3$, was discovered by XRD examination of the manufactured TiO_2/concrete composites. $CaTiO_3$ is known to show promising activity for the reduction of NOx [15].

A Haamidh et al. (2016) conducted an experiment in which sand was completely replaced with zeolite in the mortar, and to absorb a lot of CO_2 from the surfaces of the concrete cubes, zeolite plasters were applied. The concrete surface was covered with Zeolite 4A, and the material's capacity to adsorb CO_2 per square meter was examined. The strength properties of Zeolite Plastered Concrete (ZPC) were compared to those of Conventional Concrete. The results showed that the compressive strength of ZPC was higher, and the carbonation depth was reduced by 67% compared to CC, thereby lowering the potential for corrosion [16].

T.Subramani et al. (2016) investigated the mechanical and durability properties of concrete mixtures incorporating up to 25% natural zeolite (NZ) as a partial cement replacement. Results indicated that direct partial substitution of cement with NZ led to reduced compressive strength, particularly at early ages, and decreased tensile splitting strength. To mitigate this, silica fume was introduced to enhance the concrete's performance. The ternary blend (cement, zeolite, and silica fume) demonstrated superior mechanical properties compared to the binary blend (cement and zeolite). The research involved split tensile strength, compressive strength, and acid attack resistance tests [17].

D Nivethitha et al. (2016) studied the strength and durable attributes of cement mortar containing zinc oxide (ZnO) nano particles with an average particle size of 60nm. Cement was partially substituted with ZnO at 1%, 3%, and 5% by weight. The results indicated that samples with 3% and 5% ZnO nano particles exhibited better mechanical properties than traditional mortar. Similar improvements were observed in durability properties. According to Scanning Electron Microscopy (SEM) examination ZnO nanoparticles completely fill the pores and quicken the cement particle hydration process, increasing the mechanical strength and durability of the material [18].

P. Ramu et al. (2017) evaluated concrete with a partial replacement of sand in terms of its compressive strength, split tensile strength, and capacity to absorb carbon dioxide by 10%, 20%, and 30% zeolite sand, and 10% zeolite powder. The results concluded that at 28 days, the compressive strength was 6% higher and the split tensile strength was 10% higher than conventional concrete. Therefore, the highest compressive and split tensile strength was attained with an ideal replacement ratio of 30% zeolite sand and 10% zeolite powder [19].

Vibhas Bambroo et al. (2017) evaluated the concrete's compressive and flexural strength after it had been cured by CO_2 for four and eight hours. The findings demonstrated that concrete sample' compressive strength rose by 12.3% after 4 hours of carbonation curing and by 27.7% after 8 hours, compared to water-cured specimens. Additionally, the flexural strength of prisms cured with CO_2 for 8 hours increased by 1.8% compared to water-cured specimens [20].

Young Kyu Kim et al. (2017) examined the effectiveness of the TiO_2 penetration method for on-site NOx removal on the Gyeongbu Expressway retaining wall in Korea. The results showed that the amount of sunshine had an impact on the efficacy of NOx removal; during the experimental period, the TiO_2 penetration method's on-site NOx removal efficiency rate was roughly 13%. Applied as a mixture of TiO_2 and surface penetration agents at 500 g/m², the TiO2 penetration method was found to be a feasible alternative for removing NOx gases in high-traffic areas [21].

Krishna Lekha R T et al. (2017) has considered almost zeolite expansion supportability normal water softener has permeable superstructure having 54.7% rigidity. The quantity of porosity is expanded better permeable displayed within the zeolite. Utilizing zeolite concrete will diminish the worldwide climate change record compared to the customary concrete which shows. The utilization of phillipsite to create additional natural inviting [22].

Cirajudeen. A.H. et al. (2017) has explored at impact of halfway substitution with the increase of the exchange rate of zeolite with glue, the amount of zeolite increased continuously and the activity of concrete decreased in continue mode. Replacing 5% of cement with ferrocene can distribute larger coal, compressive strength, flexural strength, and shear strength [23].

Esraa Emam et al. (2017) has considered the approximate execution of bentonite adding this material as an extra cementing component fabric expressed for typical grout blends, the rate of assimilation was diminished rate of stone joining expanded, whereas, for calcined concrete blends, the rate of retention was expanded as the rate joining expanded [24].

Anila Mary Jacob et al. (2017) analyzed the engineering attributes of concrete that includes natural zeolite as SCM in the M20 grade concrete mix in an amount of 15%, 20%, 25% and 30% is presented. Along with the structural properties the CO_2 absorption ability is also evaluated. The author determined that a 15x15x15 cm concrete block containing zeolite can absorb approximately one mole of CO_2 over a 50-day period and the split tensile strength, flexural strength and compressive strength of concrete was found to be more at 25% of zeolite at the age of 28 days when compared with conventional concrete [25].

Syed Eashan Adil et al. (2017) conducted an experimental investigation using zeolite as an additive to M30 concrete, which had already replaced cement with PPC. An effort was made to investigate the concrete's strength properties. Three Varying replacement proportions namely 10%, 20% and 30% were chosen for study concern to replacement and results were the former has attained a high strength for the replenishment of zeolite powder for 28 days when compared to conventional concrete. 30% replacement of zeolite had optimum results and absorbed 1.61 mole of CO_2 and 28.5 N/mm2 Compressive Strength was achieved [26].

Mr. Mengal G.A et al. (2018) carried out investigation on the ability of concrete roads to absorb CO_2 using natural zeolite and the impact of zeolite on the strength of M30 Grade concrete were studied by replacing 25% of the cement with zeolite. The study concluded that the direct partial substitution of cement with zeolite inclusion led to a slight reduction in compressive strength, particularly in the early stages, and weakened the concrete's resistance to tensile forces [27].

Akshat K. B. (2018) has considered around silica rage and discovered the material had tensile properties. Has been revised utilizing the fume of silica as a SCM. Whenever the fume of silica was added, the product's ductility and bending characteristics displayed identical shifts. There is no specific slant of variety while using the silica rage tangible. The expansion towards flint Smolder being solids inclined diminishes the practicality of typical concrete. The thickness of the silica smolder is comparable to ordinary cement [1].

Cristina Megías-Sayago et al. (2019) has compared the adsorption of CO_2 on three different materials: zeolite, layered double hydroxides (LDH), and zeolite-coated LDH composites. It was shown that the concentration of Al-atoms in the zeolite framework and its cation character are key factors in CO_2 capture. High pore volume and high specific surface area seem to be the key to achieving high adsorption for LDHs. Sodium-exchanged zeolites had the maximum sorption value at low temperatures [28].

Farnoosh Jokar et al. (2019) has tested examination on natural strength by polluted. Elastic coal added common zeolite-Development and structure Mater 20, the properties of 651-658 Elsevier crushed Rubber Concrete C.R.C have been enhanced by the addition of normal anionic fractional substitution. To bolster the cement-rubber relationship, the flexible module's surface is cleaned with a 1M fluid solution of sodium hydroxide. Substitute with a coarse aggregate maximum size of 9mm is crushed leather having dimensions 1-6mm, 5, 10, and 15%. Zeolite may be utilized as the basis of 5, 10, or 15% of the total cement to decrease the volume of cement utilized while enhancing the attributes of the finished product. After that, tests are being looked at, including Strengths in compressive and Brazilian tensile Flexural motion extraordinary significance Composites' index of stiffness. For M30 concrete the design is carried out. In comparison to regular concrete, mechanical qualities are diminished when we add the full proportion of rubber that has been crushed. The flexibility was boosted just in the concrete material which made for 5% out of the replacement volume of crushed rubber. Throughout, the w/c ratio remains stable at 0.48. As silica is included, specimens suffering from 5% rubber-based products, 15% zeolite, and 5% rubber products, 10% zeolite correspondingly, do well in crushing and flex testing [29].

Bruno Oliveira Bica et al. (2020) done the comparison ZnO and TiO_2's effectiveness for NOx degradation in concrete blocks, it was shown that replacing TiO_2 with ZnO results in a significant decrease in photocatalytic efficiency, which can range from 39% to 78% under all environmental circumstances. Compared to TiO_2, ZnO is less efficient because it is more sensitive to UV-A light and less sensitive to flow rate. It is only feasible to employ ZnO as a photocatalyst in pavement if its market price is substantially less than that of TiO_2 [30].

Dan Wang et al. (2020) investigated on the removal of rhodamine B by TiO_2 and SiO_2 and the results showed that SiO_2 coatings accelerated the rhodamine B removal to some extent due to their high surface area. However, excessive SiO_2 coatings reduced photocatalytic efficiencies. Adding SiO_2 could enhance the adhesion between the coating and substrates and improve the durability of the photocatalytic property, especially under harsh weather conditions. Experimental data of nanocomposites with $Ca(OH)_2$ further confirmed the formation of C-S-H gels and elucidated the reaction mechanism of the nanocomposites and the cement matrix [31].

Mr. G.N. ChavanPatil et al. (2020) performed experiment on Smog adsorbing test on concrete block by using glass chamber having size 40cm x 30cm x 30cm having two holes for inlet and outlet, Two-Wheeler, concrete and mortar cubes, two pipes, multi gas analyzer. And framed that the percentage replacement of TiO_2 in concrete shall be in between 2% to 3%, at which it is most economical and most helpful to reduce harmful pollutants such as HC and CO_2 [32].

Athul K N et al. (2020) investigated on properties of carbon dioxide absorbing concrete by substituting zeolite 4a powder and silica fume for cement in concrete of M25 Grade and cement was replaced by 5%, 10%, 15%, 20% of silica fume and zeolite combination. And concluded that to achieve both carbon dioxide absorption and strength, we can choose the combination of 7.5% zeolite and 7.5% silica fume blended concrete mix while 15% replacement of zeolite for cement gives the maximum CO_2 absorption value and 15% replacement of silica fume for cement gives the maximum compressive strength, Tensile strength and Flexural strength [1].

Hanusha Durisety et al. (2020) researched on the impact and alteration in properties of concrete after substituting various concentrations of cement with zeolites, ranging from 5%, 10%, 20%, 25%, to almost 40%, were investigated. The study concluded that concrete blocks with zeolites significantly enhance CO_2 absorption compared to standard concrete, capturing nearly 60% of the CO_2 emitted during the manufacturing process. Increase in zeolite concentration results in decrease of slump value due to the cubical and rough shape. Workability of concrete is measured by conducting slump cone test. As zeolite concentration is increased slump value is decreased decreasing the workability of concrete [33].

Mir Firasath Ali et al. (2020) performed six different experiments on M40 Grade concrete. Experimental investigations were conducted by incorporating nano ZnO at dosages of 0%, 0.2%, 0.5%, and 1% to evaluate the resulting modifications in concrete properties. The findings indicate that concrete containing a 0.5% nano ZnO admixture attained a compressive strength of 51.2 N/mm² and a split tensile strength of 5.19 N/mm² after 28 days of curing. These results suggest that cement can be effectively substituted with ZnO nanoparticles, with an optimal dosage of 0.5%.

Heyang Si et al. (2021) prepared three representative photocatalytic cement mortars of TiO_2 and examined the endurance and effectiveness of photocatalytic Nox degradation. The effects of various environmental factors, such as gas flow rate, NO initial concentration, and relative humidity, were taken into consideration when creating TiO_2 powder dispersed in cement mortar (TPC), TiO_2 supported aggregates mounted on cement mortar surface (TAS), and TiO_2 supported aggregates dispersed in cement mortar (TAD). The results show that TAS has an approximate 1.5- and 1.1-times higher capacity to remove NOx than TPC and TAD, respectively. This improvement is explained by the fact that TiO_2 photocatalysts in TAS have a utilization efficiency that is between 10 and 16 times higher than that of TPC and TAD. Under photocatalytic circumstances, the durability of TAS and TAD was evaluated through a surface abrasion resistance test. The findings reveal that TAD had exceptional resistance to abrasion, and its photocatalytic activity stayed mostly intact after undergoing a 2 mm polishing procedure. Conversely, the NOx removal in TAS samples experienced a reduction of roughly 18% [34].

Jaydeep J. Chavda et al. (2022) examined the microstructure of the CO_2 captured concrete surface using a scanning electron microscope (SEM), compared the cost of the concrete, and evaluated the compressive strength of concrete mixed with various zeolite ratios. The findings indicate that adding up to 15% of zeolite powder to concrete blocks made without cement has no detrimental effects on the specimen’s compressive strength. Maximum CO_2 reduction was observed about 25% and as the percentage of zeolite in concrete is increased, the cost of production may also increase slightly, but the environmental benefits of reducing CO_2 emissions make it a worthwhile sustainable solution [35].

Following table 1 and table 2 shows critical outcomes of literature review and comparison between various SCMs respectively.

Table 1: Critical outcomes of literature review

Sr. NO	Author	SCM Used	% change in strength	Depolluting outcomes	Remarks
1	C.S. Poon et al. (2006)	TiO_2 Slag	-	2.7 mg/hr	Recycled Paving Blocks
2	Babak Ahmadi et al. (2010)	Zeolite	+15%	30%	-

3	Heather Dylla et al. (2011)	TiO_2	-	76%	-
4	Meysam Najimi et al. (2012)	Zeolite	+15%	30%	-
5	B.Uzal et al. (2012)	Zeolite	+10%	30%	-
6	N. K. Amudhavalli et al.(2012)	Silica Fumes	0-20%	40%	Plaster
7	Marwa Hassan et al. (2013)	TiO_2	-	83%	Asphalt Pavement
8	SS lucas et al. (2013)	TiO_2	+5.2% at 1%	89% at 2.5%	Cement Mortar
9	S. Karapati et al. (2014)	P-25 (evonic Degussa)	-	-	-
10	Balraj More et al. (2014)	Zeolite	No change	10%	-
11	Sabale V.D et al. (2014)	Silica Fumes	28 days	10%	-
12	Sudarsana Rao et al. (2014)	Silica Fumes	+15%	No change	-
13	M. Sedlmajer et al. (2015)	Zeolite	360 days	45%	-
14	A Haamidh et al. (2016)	Zeolite	-	-	Zeolite tiles, Plaster
15	T.Subramani et al. (2016)	Zeolite	+25%	No Change	M25 Concrete
16	D Nivethitha et al. (2016)	Zinc Oxide	-	-	Mortar
17	P. Ramu et al. (2017)	Zeolite	+6%	28 days	Concrete
18	Vibhas Bambroo et al. (2017)	Zeolite	+4%	Carbonation depth increased	CO2 Curing in Concrete beams
19	Young Kyu Kim et al. (2017)	TiO_2	+5-15%	5-10%	Concrete Road
20	Krishna Lekha R T et al. (2017)	Zeolite	54.7%	No change	-
21	Cirajudeen. A.H. et al. (2017)	Zeolite	No change	No change	-
22	Esraa Emam et al. (2017)	Zeolite	No change	No change	-
23	Anila Mary Jacob et al. (2017)	Zeolite	+10.37%	0.77 moles at 50 days	M20 Concrete
24	Syed Eashan Adil et al. (2017)	CO_2 curing	No change	No change	M30 Concrete
25	Mr. Mengal G.A et al. (2018)	Zeolite	1-14 gms	CO2	M30 Concrete
26	Akshat K. B. (2018)	Silica Fumes	Low	No change	-
27	Farnoosh Jokar et al. (2019)	Zeolite	5-15%	5-10%	M30 Concrete
28	Bruno Oliveira Bica et al. (2020)	Zinc Oxide TiO_2	-	-	Concrete blocks
29	Dan Wang et al. (2020)	TiO_2 SiO_2	-	-	Coatings
30	Mr. G.N. ChavanPatil et al. (2020)	TiO_2	+10.42%	2.38% degradation	Smog absorbing concrete
31	Athul K N et al. (2020)	Zeolite Silica Fumes	+15.38% when mixed	0.74 mole	M25 Concrete
32	Hanusha Durisety et al. (2020)	Zeolite	+8.95%	0.93 mole	Concrete
33	Mir Firasath Ali et al. (2020)	Zinc Oxide	-	-	M40 Concrete
34	Heyang Si et al. (2021)	TPC TAS TAD	No change	32.46%	-
35	Jaydeep J. Chavda et al. (2022)	Zeolite	+11.99% at 28 days for 10% Zeolite	25.16%	M40 Concrete

Table 2: Comparison between various SCMs

Sr. No	Properties	Titanium Dioxide (TiO2)	Zinc Oxide (ZnO)	Zeolite	Silica Fumes	References
1	Change in strength	Less increase	Less as compared to TiO_2	More increase	Relatively same	11,27
2	Durability	Noticeable increase	Less as compared to TiO_2	Noticeable increase	Relatively less	2,26
3	De-polluting outcomes	Reduce NO & NO_2	Less as compared to TiO_2	Reduce CO_2	Relatively less	3,5,17
4	Common grained structure	Hexagonal	Hexagonal	Porous	Circular	6,24,26
5	Economic	Relatively less [3-4%]	Relatively High	Relatively more [10-15%]	Relatively More	25,23

IV. Conclusion

By observing the critical literatures as stated above on the use SCMs for air pollution reduction approach in the concrete, following conclusions can be drawn:

a) By analyzing the numerous literatures which utilized the various types of supplementary cementitious material used for the photocatalytic process throughout the concrete such as zeolite, ZnO, TiO_2, Silica fumes, Blast furnace slag etc.
b) Among all the active photocatalytic SCMs in powder form available in the market, in major extent for the research purpose, TiO_2 is used and it is proven to be effective in removing the oxides of nitrogen (NOx) which includes Nitrogen Monoxide (NO) and Nitrogen Dioxide (NO_2) as combined.
c) There are three types of TiO_2 powder available in the market anatase, rutile, brookite from which only two are used commercially for industrial purpose those are anatase and rutile. In the concrete it has observed from the literature that anatase type of titanium is highly photocatalytic active as compared to rutile type of titanium. So, the anatase type of titanium gives better reduction of NOx as compared to rutile type of TiO_2.
d) For the reduction of CO_2 air pollutants zeolite powder as a SCM seems to be effective as compared to other SCMs. So, in the concrete natural type of zeolite powder is widely adopted for using as SCM in concrete.
e) Apart from TiO_2 and zeolite powder there are other SCMs which are tends to be used in the concrete for the same purpose like ZnO, silica fumes, fly ash, blast furnace slag, chromium oxide, activated charcoal powder etc. But from the literature it has been observed that TiO_2 and zeolite are more effective for reduction of a particular air pollutants as compared to other SCMs.

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