GSJ: Volume 8, Issue 5, May 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

EFFECT OF CHEMICALLY ENHANCING COMPRESSIVE STRENGTH OF CONCRETE USING MICRO PARTICLE METAL OXIDES

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KeyWords
Titanium Dioxide, Zinc Oxide, Compressive Strength, Chemically enhanced M25 concrete, 7 Days, 28 Days, Micro Particles.

ABSTRACT
Concrete has been used as a construction material for building roads and housing structures since early as 6500 BC. It has been modified from the volcanic ash compound used in the early ages to the compound using in the modern era a mixture with cement, aggregates, additives, accelerators and retarders. The aim of this study is to investigate the effect of chemically modified concrete with titanium dioxide (TiO_2) and zinc oxide (ZnO) micro particles on compressive strength, tensile strength and workability. The particle sizes used are 0.22-0.23 μm titanium dioxide (TiO_2) particles and 1-8 μm zinc oxide (ZnO). The ratios for M25 concrete is 1: 1: 2 the metal oxides are added in 1%, 2%, and 5% in respective to the cement weight to test its properties. Test cubes are casted to test the compressive strength from 7 days curing and 28 days curing. Experiments reveal that the compressive strength of the chemically enhanced M25 concrete is much higher than conventional M25 concrete is much higher than conventional M25 concrete. The highest strength for 7 days and 28 days is given by 2% TiO_2 and 1% for ZnO.

Introduction

The earliest use of concrete was recorded in 6500 BC in the Syrian and Jordan regions archeologists have uncovered housing structures and floors created using concrete. There are shreds of evidence that the Egyptians used mud mixed with straw as a mortar during the period of 3000 BC they have also used approximately 500,000 tons of mortar during the construction of the Pyramids of Giza. And the Chinese civilizations have also used a form of cement to build the Great Wall of China during the same time period. The ancient Romans were the first civilization to utilize concrete widely. During 600 BC and 200 BC, the Romans successfully implemented the use of concrete for the majority of their constructions. The Romans used a mixture of volcanic ash, lime, and seawater to form the concrete the mix was then packed into wooden forms. Once it was hardened the form would be removed and concrete blocks would be used for construction. The concrete structures built by the Romans remain strong even after 2000 years. The use of concrete was withdrawn during the middle ages after the fall of the Roman Empire in 476 AD the technology of creating pozzolan cement was lost. Until the manuscripts describing the technique were found in 1414 which revitalized the use of concrete in construction (Pepin, 2017).

Concrete is vastly used in the modern era's construction. It is said to be the most generally used synthetic construction material in the world. It is only second to water as the most consumed material globally. Concrete is a combination of cement, aggregates, and water. When these ingredients are mixed, it turns into a rock-like mass. The hardening of concrete is caused by the hydration process taken place when cement reacts with water, this hardening process is continued for an extended period as a consequence the concrete gets harder as it ages. The hardened concrete is sometimes considered as an artificial rock with larger voids filled larger granular particles and smaller cementitious particles fill the smaller voids (Gambhir, 2013).

The ratios of cement, fine aggregate, and coarse aggregate differs with the grade as it affects the compressive strength of concrete. The following table elaborates on the relationship between the above mentioned ratios and compressive strength.

Grade of Concrete	*Ratios of Materials*
M10	1 : 3 : 6
M15	1 : 2 : 4
M20	1 : 1.5 : 3
M25	1 : 1 : 2

Table 1 : Concrete grades and Material ratios (Civilology, 2019)

Concrete has many beneficial properties as a construction material such as high durability, high compressive strength and the good workability of fresh concrete. Low tensile strength and its brittle nature are the only notable disadvantage of concrete. In the present era concrete is made using many variations of cement such as cement partially containing pozzolan, fly ash, blast furnace slag and regulated set of additives like Sulphur, admixtures, polymer fibers. These variations in cement used to give conventional concrete notable characteristics such as higher workability, higher compressive strength, and quick-drying concrete for marine environmental work (Neville & Brooks, 2013).
Plenty of researches is conducting to innovate concrete with good characteristics and to answer the disadvantageous characteristics of concrete. Many studies conducted using inorganic materials and concrete. These inorganic materials are mostly used as alternative materials and are partial replacements for cement in hope of sustaining virgin materials.
Recently the addition of nano and micro particles, as well as carbon nanotubes (CNT), have been of interest for the material research field where it has shown endless possibilities. Furthermore, they show that the compressive and tensile strengths can achieve higher than conventional concrete, which can also affect the workability, durability, and topography as well as the aesthetic appearance of the concrete (Rathi & Rakesh, 2000). The nano and micro particles mostly used are surrounding metal oxides, such as Alumina (Al_2O_3), Silica (SiO_2), Zirconium dioxide (ZrO_2) and Titanium dioxide (TiO_2), zinc oxide (ZnO) and Nano clay. This study aims to investigate the effect on compressive strength of chemically modified concrete with titanium dioxide and zinc oxide micro particles.
Usually to counter the weakness in tension and brittleness of concrete reinforcing steel is used. By adding metal oxides to the concrete mixture the tensile strength of concrete can be increased as well as the compressive strength and other properties such as workability, durability, permeability, and topography. Due to this the lifespan of structures will be prolonged and the reinforcing steel amount needed will be less than conventional concrete which will be more economical and sustainable. Structures using this concrete will have a relatively low carbon footprint and water footprint. In this research micro particles of Titanium dioxide (TiO_2) and Zinc oxide (ZnO) will be used as metal oxides. Because these two metal oxides have been the most utilized in nanoparticle integration and various other industries.
Titanium was first founded in 1791 in England by William Gregor. The first patents were issued for making Titanium dioxide (TiO_2) between 1910 and 1915. Titanium is found as ores it needs to convert to pure Titanium dioxide (TiO_2) it is done by either the sulfate process or the chloride process. Rutile, Anatase, and brookite are the three phases of titanium dioxide the most stable form from these three is rutile. Even though anatase and brookite are stable at room temperature it slowly converts into rutile upon temperature rising. And as being the most stable phase rutile based titanium dioxide has a wide range of uses (Kushwaha, et al., 2015). Zinc was first listed in the periodic table as an element in 1789 by Antoine Lavoisier. Even though it was in use as early in the 14th century. Zinc oxide also has many applications from sunscreen to textiles, cosmetics, pharmaceutical, energy generations and storing. Recent researches suggest that by adding ZnO the durability and strength of concrete can be improved (Singh & Tiwari, 2017).

Literature review

Nano Titanium dioxide (TiO_2) has shown great promise toward increasing the compressive strength of concrete from these above-mentioned oxides. A number of research has shown that the amount of Titanium dioxide added to the concrete mix is relatively minor than the amount of cement to considerably progress early resistance of the concrete (Sanchez.F & Sobolev.K, 2010). The permeability test results for titanium dioxide have shown that if the titanium dioxide nanoparticles are less than 4% relative to cement weight the pore structure of the concrete is improved and the lowest coefficient of permeability is attained. This is mainly because titanium dioxide nanoparticles act as fillers (Behfarnia & Keivan, 2013).
Heterogeneous photocatalysis is a rapidly evolving area in sustainable engineering. It has an abundant possibility to deal with the growing air pollution problem caused by traffic. By the addition of a photocatalyst to a widely used building material such as concrete, it creates environmentally friendly materials that can help the prevention of air pollution and self-cleaning surfaces. TiO_2 can be used as a component in building structures and paving stones to get the additional feature of purifying air when in contact with UV-light/daylight (Beeldens, 2006).
Studies also show that when nanoparticles of titanium dioxide (TiO2) are integrated with cement the compressive strength of concrete is higher than concrete without nanoparticles of titanium dioxide (TiO_2). It was discovered that by partially replacing nanoparticles of titanium dioxide (TiO_2) up to maximum limit of 2.0% the higher compressive strength could achieve, however with the percentage of partial replacement of cement with nanoparticles of titanium dioxide the workability of fresh concrete was decreased but this can be avoided by the use of superplasticizers (Nazari, et al., 2010).
Recent researches suggest that by adding ZnO the durability and strength of concrete can be improved (Singh & Tiwari, 2017). Zinc oxide also has the same applications as titanium dioxide and more. Considering the previous research results the nano-ZnO particles give cement mortar prominently higher mechanical properties compared with conventional cement mortar it was found that by replacing the cement content up to 3% ZnO the cement mortar can have beneficial effects such as improved compressive strength (Nivethitha & Dharmar, 2016).

ZnO nanoparticles are said to have a strong retarding effect on the setting time of concrete if the ZnO amount is increased than a certain amount it thoroughly stops the hydration process and the formation of mortar is stopped. The increasing percentage of ZnO particles in the concrete mix leads the concrete to have a lower compressive strength. Permeability test results in a previous report showing that the unification of ZnO nanoparticles in the concrete mixture leads to a highly permeable cement paste (Behfarnia & Keivan, 2013).Nano titanium is used to reinforce concrete the reinforcement method of nano titanium was investigated through thermogravimetric analysis, X-Ray diffraction analysis, and scanning electron microscope observation. The mechanical strength of nano titanium-reinforced concrete shows substantial growth in flexural behavior during different curing ages. The flexural and compressive strength of nano titanium-reinforced concrete at 28 days age accomplish 87% increase that is 6.69MPa and 12.26% which is 12.2 MPa with respect to reinforced concrete without nano titanium thermogravimetric analysis suggest that an accelerated cement hydration plays a leading role in the early days of curing (Han.B, et al., 2017).
Most of the previous research has been concentrated on integrating Nanoparticles with concrete. But this research is focused on integrating micro particles of metal oxides with concrete. In this research TiO_2 and ZnO have been chosen as they have shown great promise integrating as nanomaterials. Here, the rutile based titanium dioxide micro particles are used because in previous researches anatase based nanoparticles have been used also ZnO is being used due to it being more economical than nano particles. Here it is mainly concentrated on the changes of concrete characteristics by adding these oxides. Such as the effect on compressive and tensile strength, the workability (ASTM C496/C496M, 2017).

Methodology

The main work for this experiment is to fabricate the M25 concrete. The concrete cubes containing 1:1:2 proportions and 1%, 2%, 5% of both metal oxides Titanium dioxide and Zinc oxide respective to the cement weight are casted. After 7 days curing and 28 days curing the compressive strength of these cubes are tested and compared with slandered M25 concrete.

Testing Material Preparation

Cement OPC, fine aggregate, coarse aggregate, water, titanium dioxide (rutile base) particle size 0.23-0.22 µm, Zinc oxide platinum seal particle size 1-8 µm.

- ***Cement-*** Ordinary Portland Cement (OPC) of 42.5 grade (Tokyo super cement) is used which is locally available. The cement is free of lumps and the properties of cement is determined by testing established by SLS 107:2008.
- ***Sand-*** Commercially available natural Sand grain size 3mm-6mm
- ***Coarse Aggregate-*** Crushed angular aggregates 10mm-20mm nominal sizes are used
- ***95% Rutile based Titanium dioxide***

Particle Size	0.22-0.23 µm
pH Value	7.0
Moisture content	0.50%
Oil absorption	16g/100g

- ***99% Zinc Oxid***

Particle Size	1-8 µm
pH Value	7.0-7.3
Moisture content	0.05-0.15%

Test Procedure

In this research, the TiO_2 and ZnO are added in certain percentages (1%, 2%, and 5%) for concrete. Then the TiO_2 and ZnO added to the concrete are optimized for strength, workability and any topographical variations in comparison to conventional concrete. Concrete is then tested for compressive strength, tensile strength, workability.

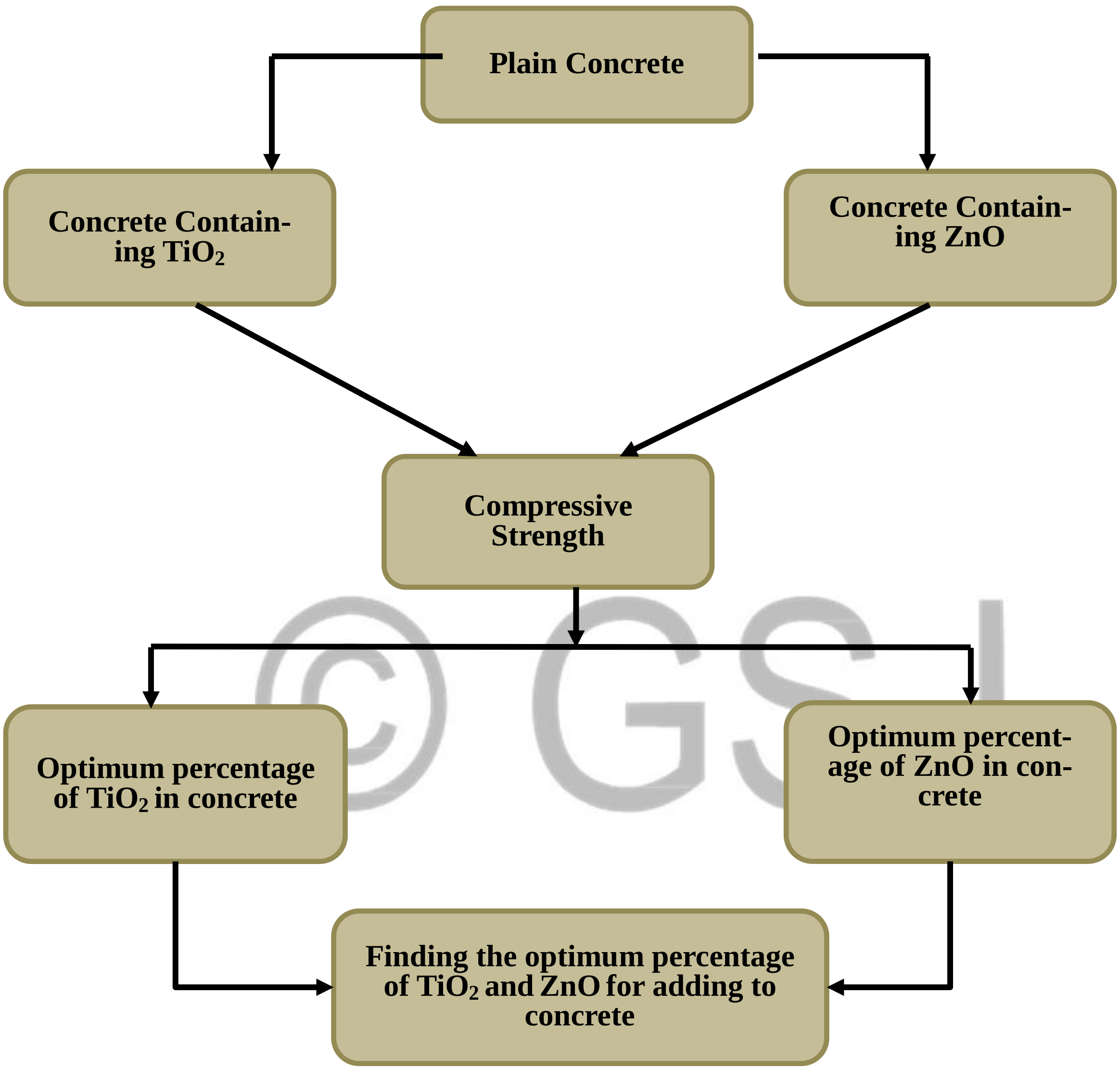

Figure 01: Methodology flow chart

In order to achieve the aims of the research, the resulting experiments are done. By doing these experiments we can compare different properties of M25 concrete which has an extra ingredient the following metal oxides TiO_2 and ZnO. The compressive strength is done using standard cube crushing where each cube is 150mm x 150mm x 150mm. And subjected to compression by the apparatus.

Compressive Strength testing

A total of 36 samples is needed for compressive strength testing. 18 samples are for testing the compressive strength after curing for 7 days and another 18 samples will be tested for its compressive strength after curing for 28 days the test cubes should be demolded after 24 hours they are casted. If after 24 hours the cubes have not achieved sufficient strength to be demolded without damaging the cubes the demolding should be delayed for another 24 hours (Virtual building and construction enviroment, 2000). When demolding the mold should be completely taken apart so that it wouldn't damage the cube.The Cubes are tested by the compression testing machine after 7 days curing and 28 days curing. The load will be applied gradually until the specimen fails and the load where the specimen is failed is recorded. The compressive strength of the test cube is given by the equation shown below (ASTM C39/C39M, 2017).

$$Compressive\ Strength = \frac{Load\ at\ faliure}{Surface\ area\ of\ the\ specimen}$$

Results & discussion

All the statistical analysis of this research has been done using SPSS 17. The results have been separated to eight groups which are shown in the below table and compared with each other using a Kruskal Wallis H test where the alpha value is $\alpha = 0.05$.

Group number	***Group Description***
1	CC M25 7 days sample
2	CC M25 28 days sample
3	TiO_2 1% added 7 days sample
4	TiO_2 2% added 7 days sample
5	TiO_2 5% added 7 days sample
6	TiO_2 1% added 28 days sample
7	TiO_2 2% added 28 days sample
8	TiO_2 5% added 28 days sample
9	ZnO 1% added 7 days sample
10	ZnO 2% added 7 days sample
11	ZnO 5% added 7 days sample
12	ZnO 1% added 28 days sample
13	ZnO 2% added 28 days sample
14	ZnO 5% added 28 days sample

Table 2: Test percentage groups

A nonparametric equivalent to a one-way anova was carried out which is the *Kruskal Wallis H Test* for 7days test results and for 28 days test results to analyze the statistical significance of the result of each test. And a post hoc test was performed to analyze the significance of percentage groups within each other.

The compressive strength test is one of the most vital tests of concrete because this gives us an idea about all the characteristics of concrete.

Percentage of added Chemical	**Average 7 Days (N/mm^2)**	**Average 28 Days (N/mm^2)**	**Average Strength of CC in 7 Days (N/mm^2)**	**Average Strength of CC in 28 Days (N/mm^2)**
TiO_2 1%	32.41 ± 0.36	40.55 ± 3.01	17.00 ± *0.01*	24.75 ± *0.01*
TiO_2 2%	38.55 ± 1.61	46.12 ± 0.90		
TiO_2 5%	33.52 ± 3.34	41.91 ± 2.95		

Table 3: Titanium Dioxide added M25 results

The primary test results for chemically modified M25 concrete and conventional M25 concrete is as shown in the table below.

Percentage of added Chemical	**Average 7 Days (N/mm^2)**	**Average 28 Days (N/mm^2)**	**Average Strength of CC in 7 Days (N/mm^2)**	**Average Strength of CC in 28 Days (N/mm^2)**
ZnO 1%	31.57 ± 0.38	44.51 ± 1.70	17.00± *0.0100*	24.75± *0.0100*
ZnO 2%	28.17 ± 1.14	40.10 ± 3.38		
ZnO 5%	29.44 ± 0.84	33.78 ± 1.16		

Table 4: Zinc Oxide added M25 results

7 Days Compressive Strength

TiO_2 added M25 concrete

A Kruskal- Wallis H test ran on groups 1, 3, 4, 5 to compare TiO_2 added M25 7 days samples with CC. it showed a value of p = 0.022 which indicates a statistically significant difference in compressive strengths between the percentage of TiO_2 added and the curing duration. The Kruskal- Wallis H test test gives a value of chi-square = 9.596 we can calculate the effect size percentage of TiO_2 added and the curing duration has on compressive strength using the equation χ^2 / N-1 and substituting the chi-square value. We get an effect size of 0.872363 which means 87.2% of the variability of compressive strength was accounted for by the groups so depending on the groups the compressive strength is more likely to vary.

Furthermore to analyze the statistical significance within each group the tukey post hoc test was performed which showed that group 1(CC M25 7 days) has a statistically significant difference with groups 3, 4, and 5. Group 3 has a statistically significant difference with groups 1, and 4. Group 5 also has a statistically significant difference with groups 1, and 4.

	Group 03 (TiO_2 1% added 7 days sample) *32.41 ± 0.36*	Group 04 (TiO_2 2% added 7 days sample) *38.55 ± 1.61*	Group 05 (TiO_2 5% added 7 days sample) *33.52 ± 3.34*
Group 01 (CC M25 7 days sample) *17.00 ± 0.01*	P = 0.000	P = 0.000	P = 0.000

Table 5.1: Post Hoc results for TiO_2 added M25 7 day samples

The post hoc test shows that all percentage groups of the chemically enhanced M25 concrete has a statistically higher compressive strength than conventional M25 concrete which establishes this study's research hypothesis regarding the addition of metal oxides to .

	Group 01 (CC M25 7 days sample) *17.00 ± 0.01*	Group 04 (TiO_2 2% added 7 days sample) 38.55 ± 1.61
Group 03 (TiO_2 1% added 7 days sample) *32.41 ± 0.36*	P = 0.000	P = 0.015

Table 5.2: Post Hoc results for TiO_2 added M25 7 day samples

Group 03 (TiO_2 1% added 7 days sample) has a significant statistical difference with group 01(CC M25 7 days sample) which is expected since all percentage groups of the chemically enhanced M25 concrete has a statistically higher compressive strength than conventional M25 concrete according to the previous post hoc test. And has a statistically significant difference with group 04 (TiO_2 2% added 7 days sample) which has the highest mean compressive strength of the TiO_2 added 7 days samples it has a significant difference of 6.140 N/mm^2 with the group 01 (TiO_2 1% added 7 days sample). The difference between group 03 and group 05 is 1.11 N/mm^2 which is not a statistically significant difference.

	Group 01 (CC M25 7 days sample) *17.00 ± 0.01*	Group 04 (TiO_2 2% added 7 days sample) *38.55 ± 1.61*
Group 05 (TiO_2 5% added 7 days sample) *33.52 ± 3.34*	P = 0.000	P = 0.042

Table 5.3: Post Hoc results for TiO_2 added M25 7 day samples

The group 05 and group 04 has a statistically significant difference. Group 04 (TiO_2 2% added 7 days sample) which has the highest mean compressive strength of the TiO_2 added 7 days samples the mean difference between these groups is 5.030 N/mm^2. By these results it can conclude that the highest compressive strength accumulated percentage group from this group set is group 04 (TiO_2 2% added 7 days sample). After obtaining the 7 days compressive strength results for TiO_2 added M25 concrete the graph was plotted using the mean values of each group to visualize the test results which shows that 2% TiO_2 added M25 concrete has achieved the highest compressive strength it is two point three times higher than conventional M25 concrete 7 days results.

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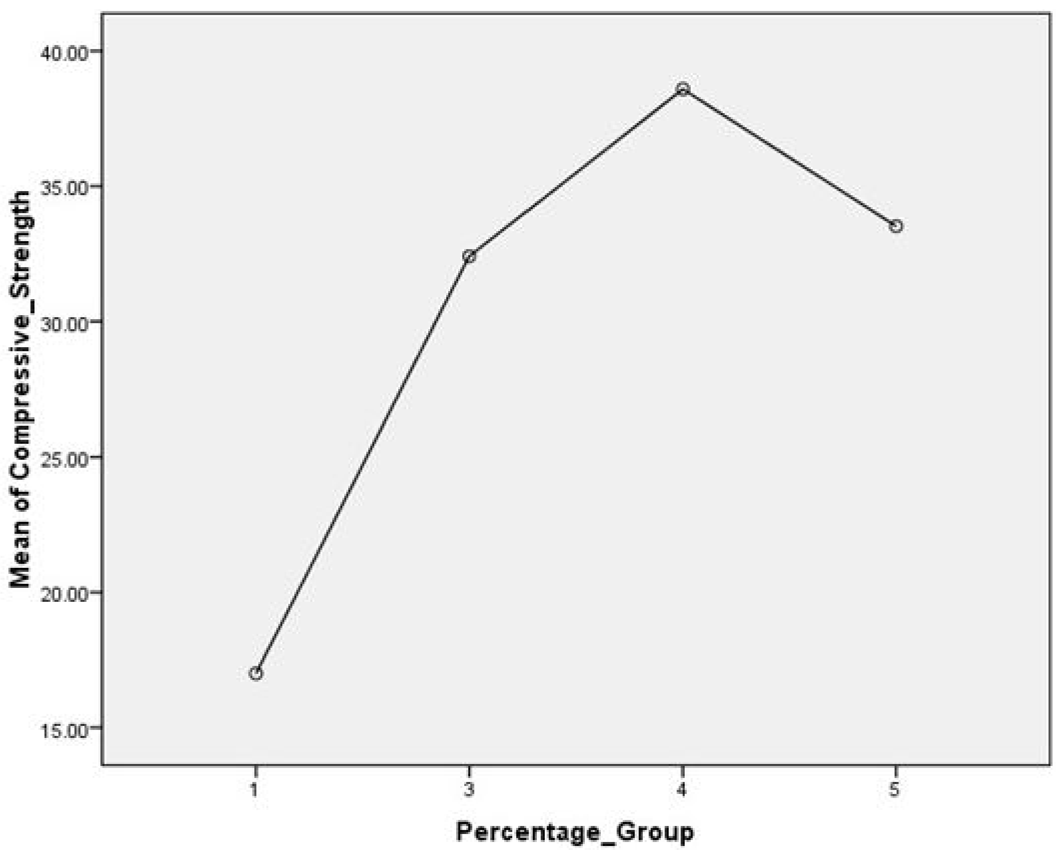


Graph 1: TiO_2 added M25 concrete 7 days mean value graph

ZnO added M25 concrete

After running a KW test on groups 1, 9, 10, and 11 which are the ZnO added M25 7 day's samples the results were it showed a value of p = 0.019 which indicates a statistically significant difference in compressive strengths between the percentage of ZnO added and the curing duration. The KW H test gives us a value of chi-square = 9.974. As previously explained the effect size can be calculated which is 0.906727 which means 90.6% of the variability of compressive strength was accounted for by the percentage groups so depending on the percentage groups the compressive strength is more likely to vary. The post hoc test was performed to further analyze any statistically significant difference between percentage groups it showed that group 01 acted as same as the previous case group 01 has a statistically significant difference with groups 9, 10, and 11. Group 09 also shows a statistically significant difference with groups 01, 10, and 11. And Group 10 and 11 has no statistically significant difference with each other.

	Group 09 (ZnO 1% added 7 days sample) *31.57 ± 0.38*	Group 10 (ZnO 2% added 7 days sample) *28.17 ± 1.14*	Group 11 (ZnO 5% added 7 days sample) *29.44 ± 0.84*
Group 01 (CC M25 7 days sample) *17.00 ± 0.01*	P = 0.000	P = 0.000	P = 0.000

Table 6.1: Post Hoc results for ZnO added M25 7 day samples

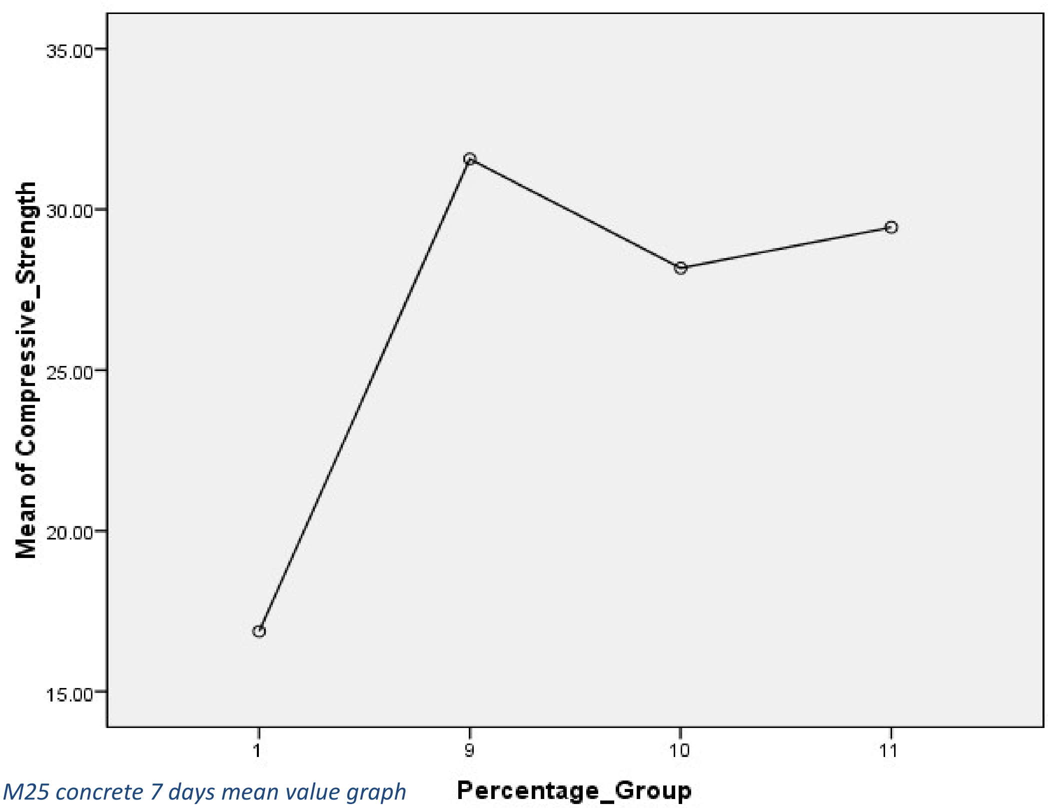
The post hoc test shows conventional M25 concrete has a statistically lower compressive strength than all percentage groups of the chemically enhanced M25 concrete. Which also establishes the research hypothesis.

	Group 01 (CC M25 7 days sample) *17.00 ± 0.01*	Group 10 (ZnO 2% added 7 days sample) *28.17 ± 1.14*	Group 11 (ZnO 5% added 7 days sample) *29.44 ± 0.84*
Group 09 (ZnO 1% added 7 days sample) *31.57 ± 0.38*	P = 0.000	P = 0.002	P = 0.033

Table 6.2: Post Hoc results for ZnO added M25 7 day samples

Unlike TiO_2 added M25 7 day samples group 09 has a statistically significant difference with group 10 (ZnO 2% added 7 days sample) and group 11(ZnO 5% added 7 days sample). While having the highest mean compressive strength it has.

The 7 days compressive strength results for ZnO added M25 concrete the graph was plotted using the mean values of each group to visualize the test results. This shows that 1% ZnO added M25 concrete has achieved one point eight six times greater than the conventional concretes compressive st



Graph 2: ZnO added M25 concrete 7 days mean value graph

As the graph shows TiO_2 added M25 concrete has greater compressive strength than conventional M25 concrete. The strength also differs from each percentage and added chemical the highest compressive strength obtained for 7 days from TiO_2 added M25 concrete was from the samples with 2% TiO_2 added M25 concrete. And as graph 2 shows the highest compressive strength for 7 days is obtained from ZnO added M25 concrete was from the 1% ZnO added M25 concrete. Which is one point eight six times greater than the conventional concretes compressive strength for 7 days.

28 Days Compressive Strength

TiO_2 added M25 concrete

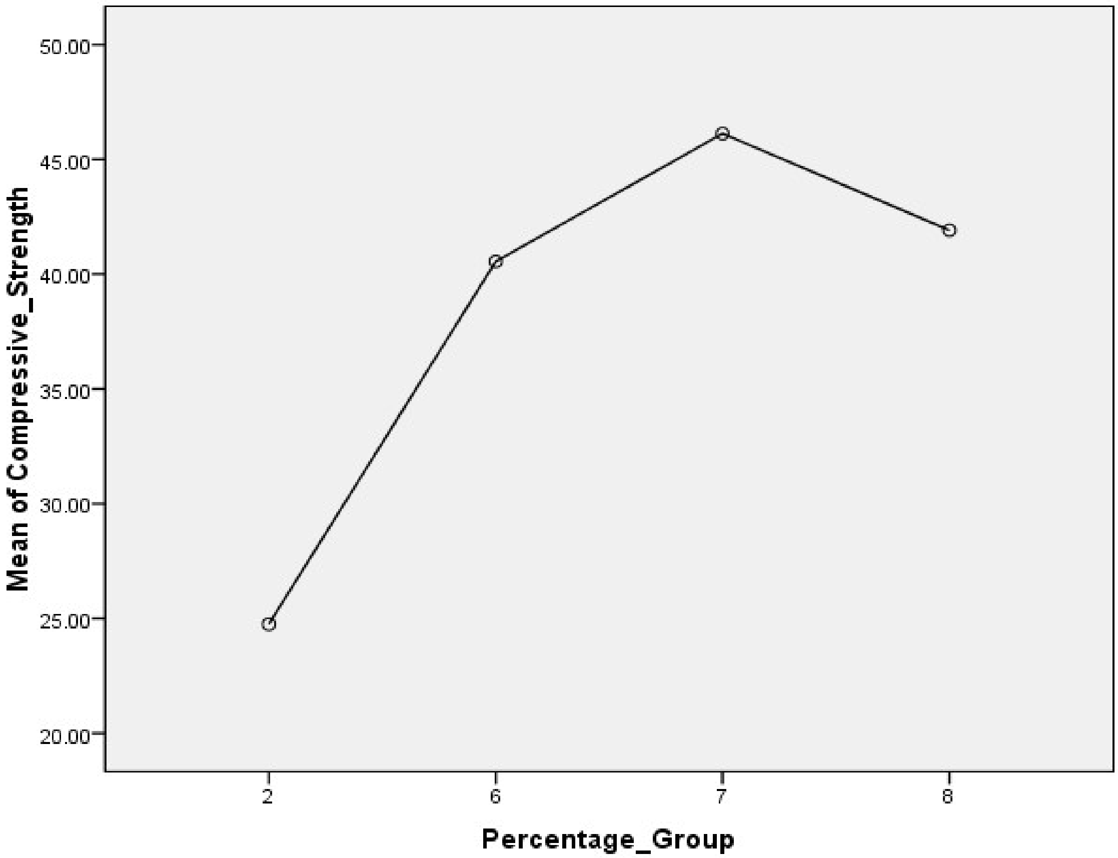
A Kruskal-Wallis test was performed on the groups 2, 6, 7, 8 which are the TiO_2 added M25 28 days samples. It showed a value of p = 0.025 which indicates a statistically significant difference in compressive strengths between the percentage of TiO_2 added and the curing duration. The KW test gives us a value of chi-square = 9.359 the calculated effect size percentage of TiO_2 added and the curing duration has on compressive strength using the equation. The effect size of 0.8508181 can be found which means 85% of the variability of compressive strength was accounted for by the percentage groups so depending on the groups the compressive strength is more likely to vary. To further to analyze the statistical significance within each group a post hoc test was performed which showed that group 02 has a statistically significant difference with group 09, 10 and 11 and the other groups has no statistically significant difference with each other.

	Group 09 (TiO_2 1% added 28 days sample) *40.55 ± 3.01*	Group 10 (TiO_2 2% added 28 days sample) *46.12 ± 0.90*	Group 11 (TiO_2 5% added 28 days sample) *41.91 ± 2.95*
Group 02 (CC M25 28 days sample) *24.75 ± 0.01*	P = 0.000	P = 0.000	P = 0.000

Table 7: Post Hoc test results for TiO_2 added M25 28 day samples

The post hoc test shows conventional M25 concrete has a statistically lower compressive strength than all percentage groups of the chemically enhanced M25 concrete. This is does not change with the curing duration.

The obtained results for the 28 days compressive strength test results for TiO_2 added M25 concrete the graph was plotted using the mean values of each group to visualize the test results which shows that 2% TiO_2 added M25 concrete has achieved the highest compressive strength even after 28 days of curing which is one point six times higher than conventional M25 concretes 28 days compressive strength.

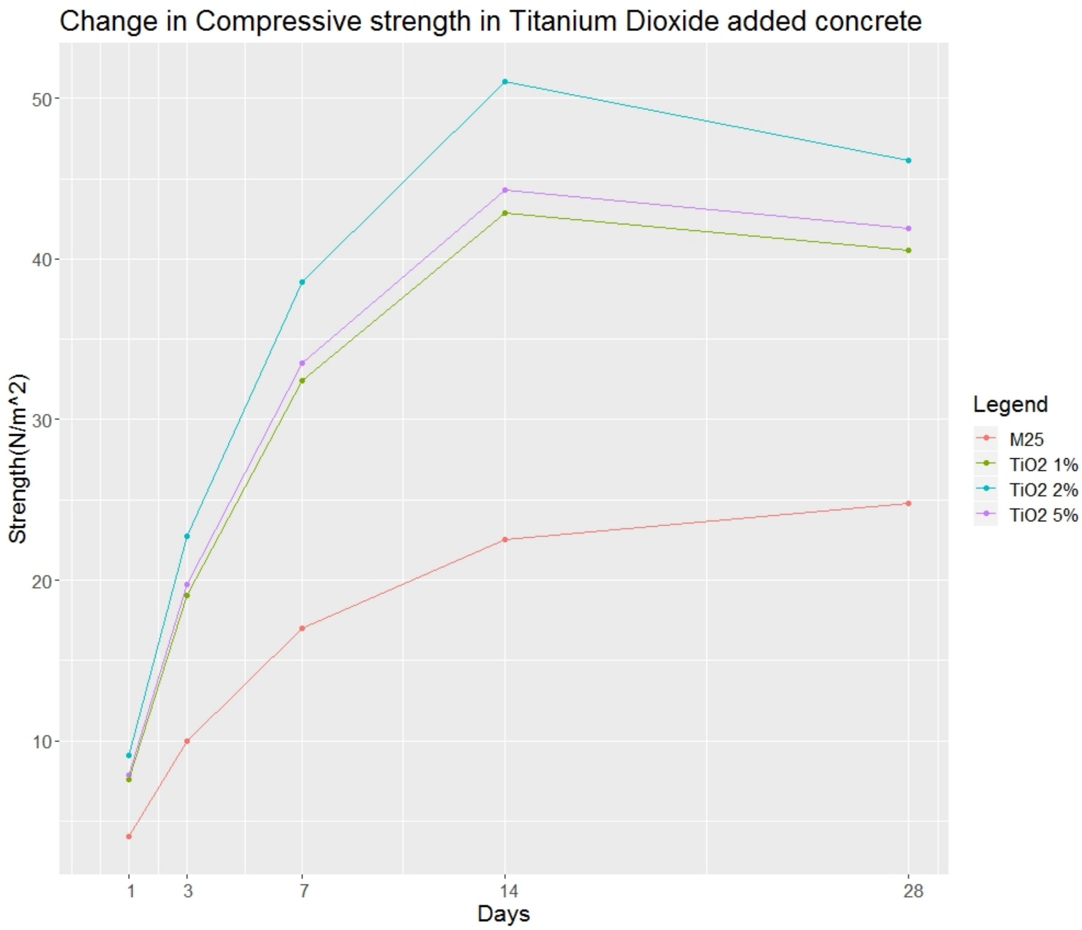


Graph 3: TiO_2 added M25 28 days concrete mean value graph

After obtaining the results from the 28 days compressive test both graphs were changed as seen below. As the graph shows the predicted strength according to concrete strength achievement percentages of M25 at 28 days has not been achieved, even though the predicted value had not been achieved the compressive strength is noticeably higher than the conventional concrete this fact can be seen in both TiO_2 added M25 concrete, as well as ZnO, added M25 concrete.

% of added Chemical	**7 Days Actual (N/mm^2)**	**28 Days Predicted (N/mm^2)**	**28 Days Actual (N/mm^2)**
TiO_2 1%	32.4	47.17	40.55
TiO_2 2%	38.6	56.16	46.16
TiO_2 5%	33.5	48.77	41.91

Table 8: Predicted values and actual values of TiO_2 added M25 concrete at 28 days



Graph 4: Compressive strength variance of TiO_2 added M25 concrete at 7 days and 28 days

It is shown that TiO_2 added M25 concrete has reached a less compressive strength than the predicted value. The highest compressive strength obtained for 28 days from TiO_2 added M25 concrete was from the samples with 2% TiO_2 added M25 concrete has a value of 46.16 N/mm^2 which is one point eight six times CC M25 28 days compressive strength. .

ZnO added M25 concrete

By performing a Kruskal-Wallis test on groups 02, 12, 13 and14 which are the ZnO added M25 28 days samples. The p value of the test was p = 0.016 and it presented a statistically significant difference in compressive strengths between the percentage of ZnO added and the curing duration. The Kruskal-Wallis test provides us a value of chi-square = 10.385 the effect size of the percentage of ZnO added and the curing duration has on compressive strength has an effect size of 0.944090which means 94.4% of the variability of compressive strength was due to the percentage groups so depending on the groups the compressive strength is more likely to vary. Additionally to investigate the statistical significance within each group a post hoc test was implemented. This showed that group 02 has a statistically significant difference with groups 12, 13, and 14. And group 12 has a statistically significant difference with groups 02 and 14 while groups 12, 13 and 14 has no statistically significant difference with each other.

	Group 12 (ZnO 1% added 28 days sample *44.51 ± 1.71*	Group 13 (ZnO 2% added 28 days sample) *40.10 ± 3.38*	Group 14 (ZnO 5% added 28 days sample) *33.78 ± 1.16*
Group 02 (CC M25 28 days sample) *24.75 ± 0.01*	P = 0.006	P = 0.039	P = 0.014

Table 9.1: Post Hoc results for ZnO added M25 concrete 28 day samples

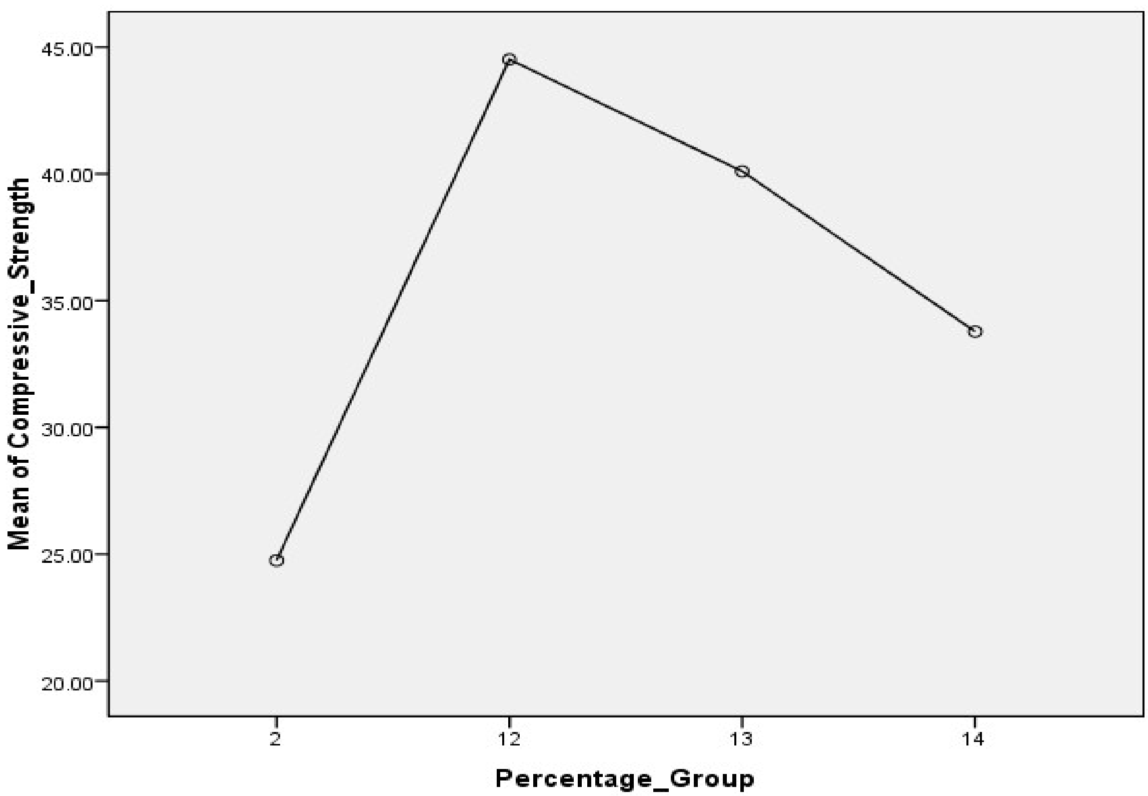
The post hoc test shows conventional M25 concrete has a statistically lower compressive strength than all percentage groups of the chemically enhanced M25 concrete. This is does not change with the curing duration or the metal oxide added.

	Group 02 (CC M25 28 days sample) *24.75 ± 0.01*	Group 14 (ZnO 5% added 28 days sample) *33.78 ± 1.16*
Group 12 (ZnO 1% added 28 days sample) *44.51 ± 1.71*	P = 0.006	P = 0.005

Table 9.2: Post Hoc results for ZnO added M25 concrete 28 day samples

Group 12 and 14 has a mean difference of 10.73 N/mm^2 between them. Group 12 has the highest mean value from this group sets while group 14 has the lowest mean value.

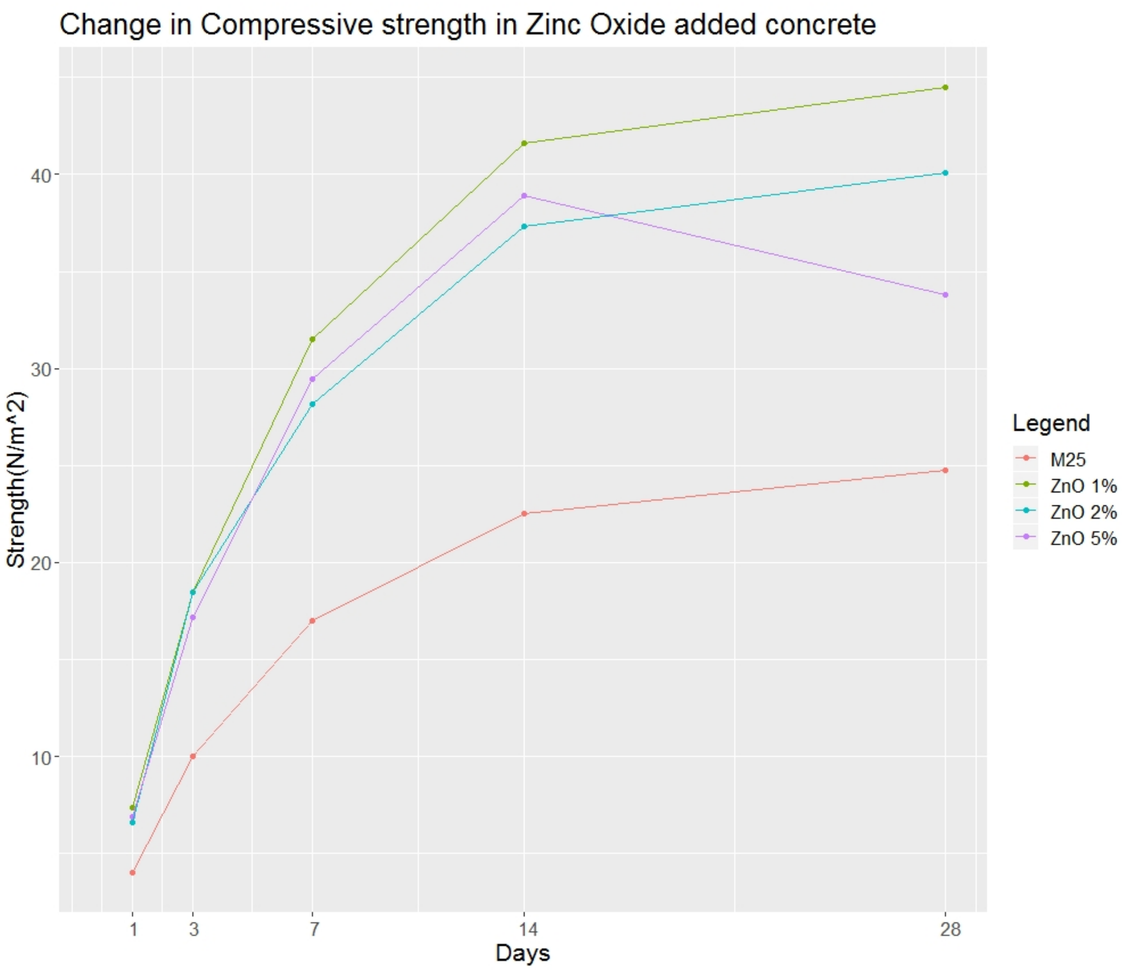
Graph 5: TiO_2 added M25 28 days concrete mean value graph



The results obtained for the 28 days compressive strength test results for ZnO added M25 concrete the graph was plotted using the mean values of each group to visualize the test results which shows that 1% ZnO added M25 concrete has achieved the highest compressive strength even after 28 days of curing which is one point eight times higher than conventional M25 concretes 28 days compressive strength. It can be seen that the 1% ZnO added M25 concrete has also improved its strength compared to the 7 days cured samples.

% of added Chemical	7 Days Actual (N/mm^2)	28 Days Predicted (N/mm^2)	28 Days Actual (N/mm^2)
ZnO 1%	31.6	45.8	44.51
ZnO 2%	28.2	41	40.10
ZnO 5%	29.4	42.8	33.78

Table 10: Predicted values and actual values of ZnO added M25 concrete at 28 day



Graph 6: Compressive strength variance of ZnO added M25 concrete at 7 days and 28 days

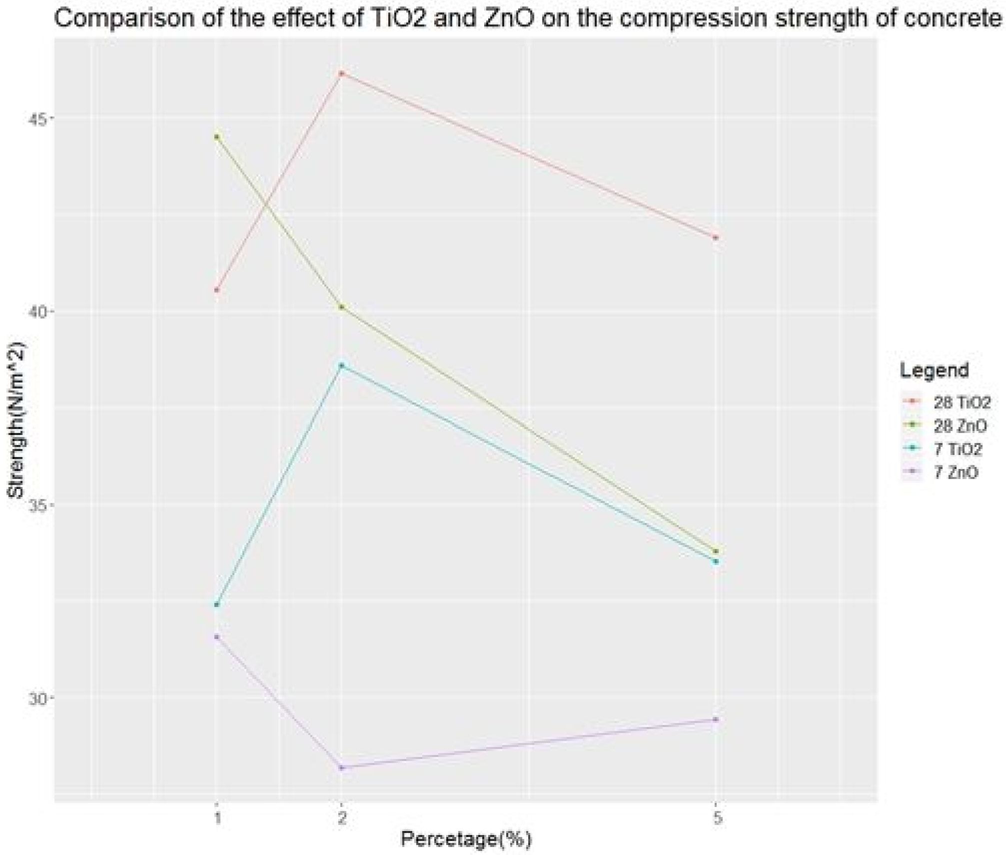
And graph 4 and table 5 shows that the highest compressive strength value at 28 days of ZnO added M25 concrete is obtained from the 1% ZnO added M25 concrete samples. The compressive strength value for 1% ZnO added M25 concrete is 44.51 N/mm^2.

Comparison of TiO_2 & ZnO added M25 concrete Compressive Strength

As the test results show the highest compressive strengths achieved by TiO_2 added M25 concrete is given by adding 2% of TiO_2 for both 7 days and 28days. And the highest compressive strength achieved by ZnO added M25 concrete is obtained by adding 1% of ZnO for both 7days and 28 days.

Percentage & Chemical compound	Maximum Compressive strength obtained for 7 days (N/mm^2)	Maximum Compressive strength obtained for 28 days (N/mm^2)
TiO_2 2%	38.6	46.16
ZnO 1%	31.6	44.51

Table 11: Maximum Compressive Strengths obtained by adding each chemical



Graph 7: Comparison of TiO_2 & ZnO percentages affect the compressive strength of the M25 concrete

Conclusion

The results gained in this study shows that by adding TiO_2 micro particles and Zinc Oxide micro particles the compressive strength and tensile strength can be increased. The compressive strength of concrete is highest of TiO_2 added concrete is when 2% Titanium dioxide (TiO_2) is added. It achieves a compressive strength of *38.59 N/mm^2 after 7 days of curing* and after further curing the sample for *28 days it achieves a strength of 46.16 N/mm^2* which is 99% of the strength it achieves. And the compressive strength of concrete is highest of ZnO added concrete is when 1% Zinc Oxide (ZnO) is added. After curing for 7 days it achieves a compressive strength of 31.57 N/mm^2 when cured up to 28 days the sample reaches a compressive strength of 44.51 N/mm^2. By adding both types of micro particles it allows to exceed the original characteristic compressive strength (f_{ck}) value of M25 concrete the f_{ck} value of conventional M25 after curing for 28 days is 24.75 N/mm^2 even though both TiO_2 and ZnO particles affects the compressive strength the highest compressive strength is achieved by adding 2% TiO_2 relative to the cement weight used. For further research these samples can be subjected to a scanning electron microscope (SEM) analysis and the pore structure could be viewed. By that any topographical variations may have happened due to the added ingredient can be identified and be rectified if needed. And the percentages of the samples can be taken in smaller intervals such as adding the metal oxides in 0.5%, 1%, 1.5%, and 2% to be even more accurate with the results.

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