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Effect of Nano-Tio_2addition on Mechanical Properties of Concrete and Corrosion Behavior of Reinforcement Bars

Mosad Mohamed Sadawy[1] and EltohamyRabie Elsharkawy[2]
[1]Faculty of Engineering, Al-Azhar University, Cairo, Egypt
[2]Nuclear & Radiological Regulatory Authority. Cairo, Egypt

ABSTRACT
Concrete science is a multidisciplinary area of research where nanotechnology potentially offers the opportunity to enhance the understanding of concrete behavior, to engineer its properties and to lower production and ecological cost of construction materials. The main objective of this research was to evaluate the effect of nano-TiO_2on compressive strength,bond strength and corrosion behavior of reinforcement bars. It has been found that the compressive strength, bond strength and corrosion resistance was increased with increasing nano-$TiO_2$to 1.5wt. % as replacement of cement. Beyond this value, these properties decrease.

I. INTRODUCTION

In nuclear energy systems, the major construction inputs are steel and concrete, which comprise over 95% of the material energy inputs. The evaluation of construction material inputs is central to life-cycle assessments for environmental impacts for nuclear and other non-fossil energy systems, and can provide a useful, if only qualitative, plausibility check for economics claims[1,2].

In recent years, there is a global interest in the investigation of the influence of nanomaterial in construction materials especially cement mortar and concrete. Nanomaterial due to its small size possess unique properties such as high specific surface area and high activity. If nanomaterials are combined with traditional building materials, this may lead to production of building materials with unique properties.[3]. The use of nanomaterial can not only modify properties by potentially enhancing strength and durability but also by introducing new functionality, including photocatalytic, anti-fogging and self-sensing capabilities [4].

Titanium dioxide (TiO_2) is added as a filler to cement for its photocatalytic activity which have been mainly used to remove organic pollutants from surfaces directly exposed to ultraviolet radiations such as road pavements. Research has shown that the photocatalytic activity is superior in nano-crystalline TiO_2 and that it exhibits maximum efficiency in anatase phase compared to rutile or brookite phase [5,6]. When added to Portland cement, TiO_2 is considered to act as inert filler and has not been believed to take part in the hydraulic reaction of Portland cement.It has recently been reported that the TiO2 nanoparticles accelerated the rate of hydration and increased the degree of hydration [7,8].

The main objective of this work is to evaluate the effect of nano-TiO_2 on compressive strength, bond strength and corrosion behavior of reinforcement bars.

II. EXPERIMENTAL WORK

2.1. Materials

The present study was performed using a commercial Portland Type type CEM I 42.5N meeting the requirements of BS EN 197-1:2000. Nano-TiO_2particles were delivered in 100-g package with particle size 30 nm Figures (1and2) .Aggregates: natural siliceous sand having a fineness modulus of 2.66 and a specific gravity of 2.67 was used. Crushed dolomite with a maximum nominal size of 18 mm was used as coarse aggregate. The aggregate had a specific gravity of 2.64 and a crushing modulus of 23 percent. High tensile ribbed steel bars of 13 mm diameter were cut into 15 and 50 cm for corrosion and bond strength tests respectively. The water used was taken from portable water supplies.

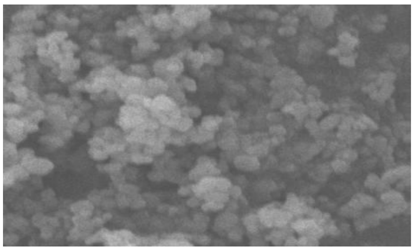

Figure 1. Nano-TiO_2 particles

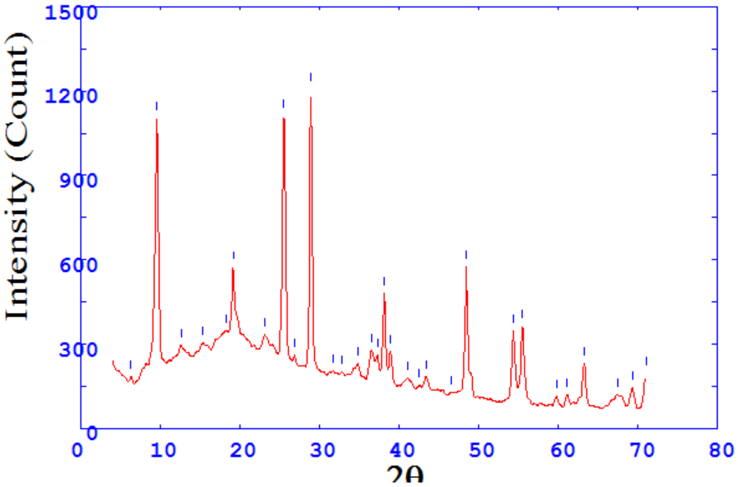

Figure 2- XRD analysis of TiO_2 nanoparticles

2.2. Preparation of test specimen

To disperse mineral additives uniformly they were added into water and stirred at high speed. The sand and gravel were place in the mixer and start the mixer. Then the cementations materials were added to the mixer and stirred for 1 min. The mixing water was slowly added and mixed for 2 min. Mixing was continued for 5 min; the mixer stopped for 3 min, and then continued mixing for an additional 2 min. Upon completion of mixing, place the fresh concrete into the molds to form the cubes of size 15×15×15 cm for all mixing proportion and tests.After 24 hours, the specimens were demoulded and cured in water for 28 days.Each water-cured cube was taken from water at each of the test age and then rubbed with a clean dry cloth until a saturated surface dry sample was obtained.

2.3. Compressive strength tests

The compressive strength test was conducted by crushing three cubical concrete specimens of 150 mm at 28 days in accordance with ASTM (1996-2013b). The average of the three tests at each period was reported.

2.4. Bond strengthtests

The bond strength of steel substrate with concrete structure was evaluated by pull-out method.The reinforcing bars have a nominaldiameter of 10 mm. The load was applied at a loading rate of 0.075 kN /s. The bond stress is calculated using the following expression equation:

$$\tau = \frac{P_{max}}{\pi . \phi . l} \qquad (1)$$

Where τ is the bond strength; P_{max} is the maximum pullout load; Φ is the bar diameter; and l is embedment length of bar.

2.5. Corrosion tests

Cubic specimens with an edge of 150 mm were prepared. The bar was positioned in the centre of the mould. Steel bar and concrete are only bonded in half length of the cubic specimen, in order to exclude an eventual confinement of the concrete surrounding the rebar due to the stress distribution on the specimen surface in contact with testing rig. During the specimen casting, concrete was placed in the moulds in the perpendicular direction of the bars.

The corrosion analysis was performed by A Potentiostat/Galvanostat (EG&G model 273). A three-electrode cell composed of a specimen as a working electrode, graphite counter electrode, and Ag/AgCl reference electrode were used for the tests. Polarization tests were carried out at a scan rate of 0.2 mV/s at room temperature. Specimens with exposed surface area of 10 cm^2 were used as a working electrode. The PAR CalcTafel Analysis routine statistically fits the experimental data to the Stern-Geary model for a corroding system. The routine automatically selects the data that lies within the Tafel region (±250 mV with respect to the corrosion potential). It then calculates the corrosion current and the corrosion rate. The solutions were prepared using analytical reagent grade chemicals and distilled water.

2.6. Surface Analysis

Scanning electron microscope (SEM) was used to observe the microstructure of concrete with and without silica particles additives. All samples were coated with gold to improve the appearance of microstructure.

III. RESULTS AND DISCUSSIONS

3.1. XRD analysis

Fig. 3 shows the results of XRD for concrete with TiO_2. It can be seen that TiO_2 only can be filled among the cement particles to make hardened concrete compact and to improve the interface structure and performance [9].

3.2. Effect of nano- TiO_2 additives on compressive strength of concrete

The compressive strengths have been evaluated from the peak load obtained by crushing the specimen. The compressive strength after 28 days for $TiO_2$is shown in Fig. 4. As can be observed the mechanical strength depends on the amount of nano-TiO_2 added. Strength enhancement can be attributed to that nano particles can act as nuclei for cement phases, further promoting cement hydration due to their high reactivity, as nano reinforcement, densifying the microstructure and the interfacial transition zone, thereby, leading to a reduced porosity. Also, nano particles would fill pores to increase the compressive strength [10,11]. Moreover, Fig. 4 indicates that the compressive strength increases with increasing TiO_2 content from 0.5 to 1.5 wt. % replacement of cement beyond this amounts the strength decreases. This behavior is attributed to agglomeration of TiO_2particles which exert more voids in concrete and decreases of C_3Scontent[12].

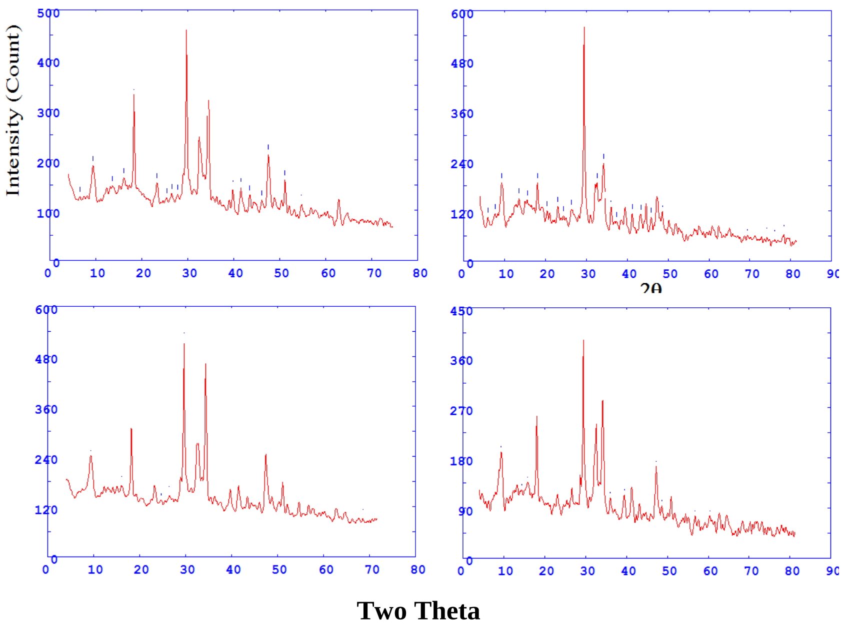

Fig.3 XRD differaction of concrete with TiO_2at 28 days. , (a)- 0.0 wt.%TiO_2, (b)-0.5 wt.% TiO_2, (c)-1.5 wt.% TiO_2 ,(d)-2.5 wt.% TiO_2

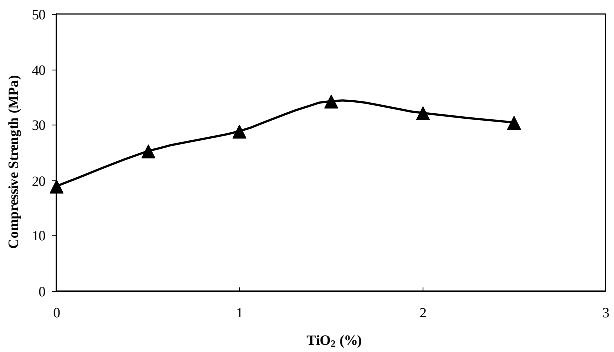

Fig.4 Effectof nano-TiO_2 on compressive strength of concrete

3.3. Effect of nano- TiO_2additives onbond strengthof concrete

The bondstrength results are shown in Fig. 5. Similar to the compressive strength, the bond strength of the specimens increases with nano- TiO_2 to 1.5 % replacement. Moreover, Fig. 5 indicates that beyond 1.5 % replacement the bond strength decreases for concrete with TiO_2 contents. This behavior attributed to agglomeration of nano- TiO_2 which cause more voids and variation in size of internal grains[13,14].

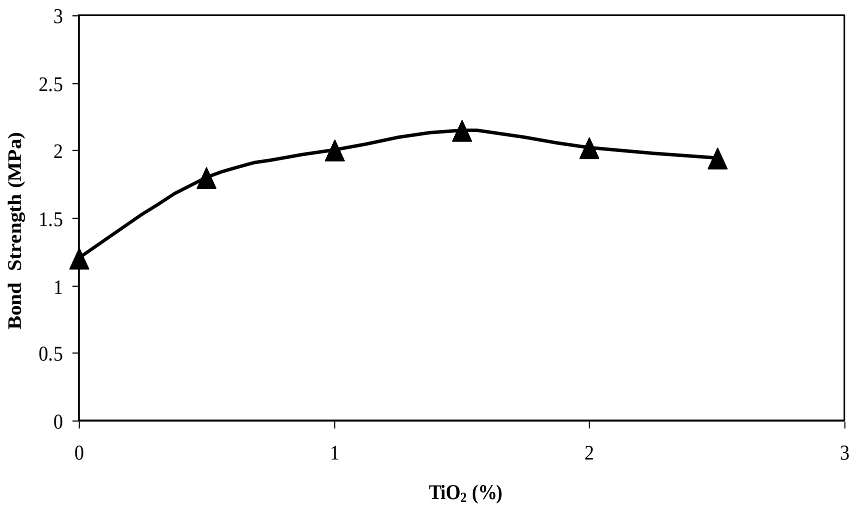

Fig.5 Effect of nano-TiO_2 additives on bond strength of concrete

3.4. Effect of nano- TiO_2additives oncorrosion of reinforced steel bars imbedded in concrete

The corrosion speed of reinforcedsteel bars in a 3.5 % NaCl solution was studied by electrochemical method.

Fig. 6indicates the corrosion and electrochemical of steel with and without of nano- TiO_2 additives. It can be seen from Fig6 that the corrosion rate decreases with increase nano-TiO_2 additives from 0.5 to 1.5 wt. % replacement of cement beyond this amount the corrosion rate increases. Also this behavior is attributed to agglomeration of nano-TiO_2additiveswhich exert more voids in concrete these voids allow to water to penetrate and contact with steel bars. Therefore electrochemical reaction occurs and increases with increasing voids[15].

IV. CONCLUSIONS

The results show that nano- TiO_2 additivesblended concrete had higher compressive, bond strengths and corrosion resistance compare to that of the concrete without nano- TiO_2 additives. It is found that the cement could be advantageously replaced with nano- TiO_2 additives up to maximum limit of 1.5 wt. %.

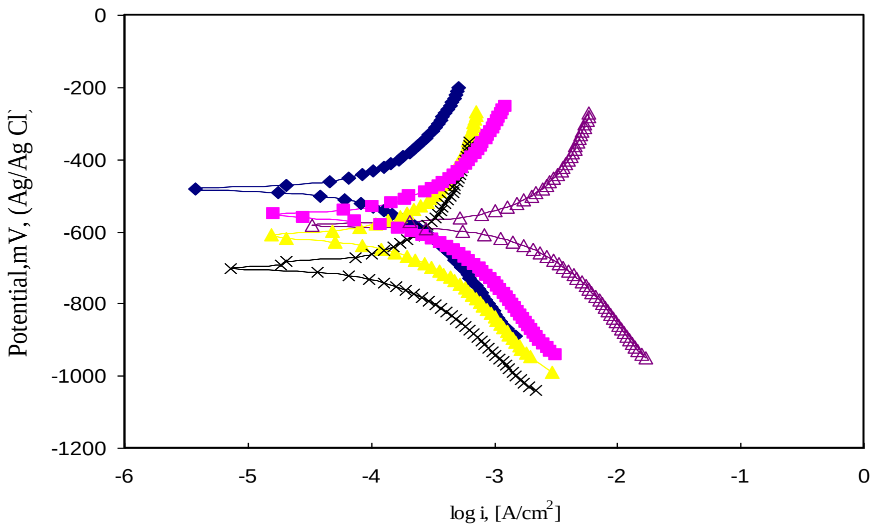

Fig.6 Effect of TiO_2 additives oncorrosion of reinforced steel bars imbedded in concrete

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