

- 2- A similar finding of those specimens with BIO and specimens with BS was also observed with the addition of TiO.
- 3- A significant increase in slump was measured in concrete specimens with PAA. An average of 24% increase in slump with every percent increase in PAA was obtained.
- 4- There was an also increase of 6.4 % and 3.4 % in the 7 days compressive strength of concrete at every 0.5 % increase in specimens with BIO and specimens with BS respectively.
- 5- The addition of 1 % TiO and 1 % PAA by cement weight to concrete gave 18.5 % and 6.3 % improvement in the 7 days compressive strength, respectively. This gain in strength started to decrease beyond the 1 % TiO and 1 % PAA with a decreasing rate of 1.34 % and 0.7 % respectively at every 1% increment of these NM.
- 6- An improvement of 6.9 % and 3.0 % in the 28 days strength was measured at every percent increase of BIO and BS to the concrete, respectively. The total improvement obtained in the 28 days strength at 2.5 % of BIO and 2.5 % BS by cement weight was 34.3 % and 15.2 %, respectively.
- 7- The maximum strength of 3.6 % and 16 % for the PAA specimens and TiO specimens was obtained at 1% content of each of them, respectively. Beyond this 1 % content of PAA and TiO, there was a loss in the gained strength.
- 8- The addition of 5 % PAA to the 2.5 BIO specimens increased the slump from 90 mm to 170 mm (88.9 % increase) and improved the 28 days compressive strength from 37.37 kg/cm² to 49.35 kg/cm² (32.1 % increase).
- 9- By adding 5 % PAA to the 1 % TiO specimens, the slump increased from 90 mm to 145 mm (61.1 % increase) and the 28 days compressive strength improved from 37.37 kg/cm² to 44.12 kg/cm² (18.1 % increase).
- 10- Adding 5 % PAA to the 2.5 % BS specimens gave an increase in slump from 108 mm (for BS alone) to 150 mm with 5 % PAA and 2.5 % BS together. Also, a slight enhancement of 8.1 % was obtained in the 28 days compressive strength.

VI. ACKNOWLEDGMENT

The authors would like to express their thanks and appreciation to all technical staff at the Materials and Soil Lab. At the Islamic University of Gaza, The Gaza Strip, Palestine for their continuous support during the course of preparation of the current study.

VII. REFERENCES

- [1] Transportation Research Circular, " Nanotechnology in Concrete Materials," A Synopsis Prepared by B. Birgisson, A.K. Mukhopadhyay, G. Geary, M. Khan and K. Sobolev, " No. E-C170, 2012.
- [2] F. Sanchez, and K. Sobolev, " Nanotechnology in concrete – A review," Construction and Building Materials, vol. 24, pp. 2060-2071, 2010.
- [3] S. Zhao, and W. Sun, " Nano-mechanical behavior of a green ultra-high performance concrete," Construction and Building Materials, vol. 63, pp. 150-160, 2014.
- [4] A.M. Rashad, "A synopsis about the effect of nano-Al₂O₃, nano-Fe₂O₃, nano-Fe₃O₄ and nano-clay on some properties of cementitious materials – A short guide for Civil Engineer," Materials and Design, vol. 52, pp. 143-157, 2013.
- [5] M.H. Beigi, J. Berenjian, O.L. Omran, A.S. Nik, and I.M. Nikbin, "[An experimental survey on combined effects of fibers and nanosilica on the mechanical, rheological, and durability properties of self-compacting concrete.](#)" Materials and Design, vol. 50, pp. 1019-1029, 2013.
- [6] W. Zhu, P.J.M. Bartos, and A. Porro, "Application of nanotechnology in construction, Summary of a state-of-the-art report," Materials and Structures, vol. 37, pp. 649-658, 2004.
- [7] A.H. Shekari, and M.S. Razzaghi, "Influence of Nano Particles on Durability and Mechanical Properties of High Performance Concrete", Procedia Engineering, vol. 14, pp. 3036-3041, 2011.
- [8] M. Jalal, M. Fathi, and M. Farzad, "Effects of fly ash and TiO₂ nanoparticles on rheological, mechanical, microstructural and thermal properties of high strength self-compacting concrete," Mechanics of Materials, vol. 61, pp. 11-27, 2013.
- [9] I. Karatasios, V. Kilikoglou, P. Theoulakis, B. Colston, and D. Watt, "[Sulphate resistance of lime-based barium mortars.](#)" Cement and Concrete Composites, vol. 30, Issue 9, pp. 815-821, 2008.
- [10] K. Mermerdaş, E. Güneyisi, M. Gesoğlu, and T. Özturan, "[Experimental evaluation and modeling of drying shrinkage behavior of metakaolin and calcined kaolin blended concretes.](#)" Construction and Building Materials, vol. 43, pp. 337-347, 2013.
- [11] L. Hyun-Soo, L. Jae-Yong , and Y. Myoung-Youl, "[Influence of iron oxide pigments on the properties of concrete interlocking blocks.](#)" Cement and Concrete Research, vol. 33, Issue 11, pp. 1889-1896, 2003.
- [12] S.A. Al Mishhadani, A.M. Ibrahim and Z.H. Naji, "The effect of nano metakaolin material on some properties of concrete," Diyala Journal of Engineering Sciences, vol. 06, No. 01, pp. 50-61, 2013.
- [13] R. Yu , P. Spiesz, H.J.H. Brouwers, "Effect of nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete (UHPC) with a low binder amount," Construction and Building Materials, vol. 65, pp. 140-150, 2014.
- [14] K.G. Sharobim, and H.A. Mohammedin, "The effect of Nano-liquid on the properties of hardened concrete," HBRC Journal, vol. 9, Issue 3, pp. 210-215, 2013.
- [15] ASTM C191, "Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle", American Society for Testing and Material Standard Practice C191, Philadelphia, Pennsylvania, 2004.
- [16] ASTM C109, "Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)", American Society for Testing and Material Standard Practice C109, Philadelphia, Pennsylvania, 2002.
- [17] ASTM C0136, "Test Method for Sieve Analysis of Fine and Coarse Aggregates", American Society for Testing and Material Standard Practice C136, Philadelphia, Pennsylvania, 2005.
- [18] ASTM C204, "Test Method for Fineness of Hydraulic Cement by Air-Permeability Apparatus", American Society for Testing and Material Standard Practice C204, Philadelphia, Pennsylvania, 2000.
- [19] ACI Committee 211, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete", 2002.
- [20] ASTM C191, "Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle", American Society for Testing and Material Standard Practice C191, Philadelphia, Pennsylvania, 2004.
- [21] ASTM C0143, "Test Method for Slump of Hydraulic-Cement Concrete," American Society for Testing and Material Standard Practice C143, Philadelphia, Pennsylvania, 2005.
- [22] ASTM C39, "Test Method for Compressive Strength of Cylindrical Concrete Specimens," American Society for Testing and Material Standard Practice C143, Philadelphia, Pennsylvania, 2004.