ISSN: 0974-5823 Vol. 7 No. 5 May, 2022

International Journal of Mechanical Engineering

The Effect of Nano Barite Powder on Compressive Strength of Concrete and its effect on environment pollution

Ali Akbar Roshanasan and Javad Nasiri Rajabli*

Department of Civil Engineering, Azadshahr Branch, Islamic Azad University, Azadshahr, Iran

Abstract - Heavy concrete was used in the building industry for a long time, and this type of concrete was first used to enhance the safety of specific buildings, such as preventing slippage and safety against overturning. However, heavy concrete is used, not only due to their weight, but for resistance against nuclear radiations. Barite aggregates are one of the most influential additives in the production of heavy concrete. In this study, in order to evaluate the possibility of using heavy concrete, as structural concrete, instead of barite, Nano barite was used to study the effect of this material on Nano scale dimensions on concrete mechanical properties. For this purpose, concrete samples were used with compressive strength class of C15, C25 and C40 with replacement of different values of Nano barite from 1% to 9% by weight of cement and comparing their compressive strength with control sample, in perfectly equal conditions. Based on experimental results, it was found that the addition of Nano barite powder did not significantly reduce the structural characteristics of the concrete. The highest compressive strength of the concrete is achieved at 28 days, by adding 5% of Nano barite to concrete**.** By decreasing the concrete strength class, the percentage of increasing the concrete strength increases and by increasing the concrete strength class, the percentage of increasing the concrete strength decreases. This increase in strength for concrete of C15 was 29% and for concrete of C40 was 5%. The compressive strength of the concrete will be decreased and declined by increasing the Nano barite percentage by more than 5%. In addition, one the most important results of using Nano barite instead of barite in concrete is decrease of environment pollution.

Keywords: Compressive Strength, Concrete, environment, Nano Barite powder.

INTRODUCTION

Concrete is one of the most commonly used construction materials that is widely used in the construction of various structures due to its low cost, ease of use and compliance with the required conditions. Since the use of concrete by Romans until 1824 and the construction of Portland cement by Joseph Spedin [1], humans have sought to improve the properties of concrete through the modification or addition of stone and non-stone materials. The use of additives to concrete is an idea that has been proposed in recent years to improve the qualitative and environmental indicators and, thus, prevention of pollution emissions to water and soil resources. The disadvantages of increasing cement production have led to extensive research for the use of additives in concrete in recent years to improve its properties and reduce cement consumption in different countries of the world. The advancement in the production of materials and the ever-increasing research into the materials of concrete constructions have provided material that, in turn, has been able to exert great effects on concrete production with improved mechanical and non-mechanical properties.

Heavy concrete is one of the types of concrete that has become very popular in recent years. Based on the definition of the ACI Institute; heavy concrete is essentially of a higher specific weight than ordinary concrete. Instead of sand and gravel, small particles of steel, iron or barite are used in the construction of heavy concrete. The specific weight of heavy concrete is about 1.5 to 2.5 times higher than the specific weight of ordinary concrete. According to the type and size of used aggregates and the method of compacting and discharging, heavy concrete can have a specific mass of more than 6400 kg/m3[2].

Heavy concrete is specifically used as a protective shield against radiation from nuclear power plants and research centers, and medical and industrial units. The choice of concrete for radiation protection depends on the type and intensity of radiation and the space requirements. The efficiency of concrete protection against radiation is proportional to the specific mass of the concrete. More specific mass produces more effective protection. The most important factor in obtaining heavy concrete production is the choice of suitable aggregate for it. Heavy concrete aggregates should have the minimum criteria and regulations for the aggregates used for the production of radiation protective concrete in accordance with ASTM C637 and ASTM C638 standards. The specific weight of ordinary aggregates is about 2400 kg /m3 and for heavy aggregates it will be 4400 kg /m3, which these numbers indicate the importance of the type of aggregates used in the properties of heavy concrete. Barite is one of the most popular aggregates in heavy concrete production. Barite has a high specific weight (4.6 to 4.3 gr /cm3) and is used to prevent the radiation from passing through concrete walls to produce heavy concrete in nuclear power plants [3, 4].

In recent years, some researches have been carried out about the use of barite in the production of heavy concrete. In 2003, Topcu conducted a study on heavy concrete with different mixing ratios of water and cement to determine the best mixing ratio of produced heavy concrete with barite particles. The results showed that the optimum ratio of water to cement was 0.4 and the cement content should not be less than 350 kg /m3 [5]. Akkurt et al. [6, 7] evaluated the gamma ray transmission from concrete containing barite in various energies, and found that while lead is an ideal protective material for prevention of gamma ray transmissions, the use of barite in concrete, as an aggregate, can be used as an alternative protection material in the construction of an insulating wall. Vahidnia et al. [8] studied the physical and mechanical properties of concrete made with barite with volumetric ratios of 0, 10, 20, 30, 40, and 50. The results of this study showed that the unit weight, modulus of elasticity, ultrasonic pulse velocity and concrete heat conductivity coefficient increased with a water-to-cement ratio of 0.6 in parallel with increasing the ratio of barite particles. However, Schmidt hardness, water absorption, compressive and torsion strength decreased by increasing barite ratio. Ortega and Aguado in 2015, evaluates the friability of the barite aggregate during the mixing process and its influence on the fresh and hardened properties of concrete. In this research, three types of aggregates were studied: barite (in two states, dry and wet), limestone and EAF slag. A specific test was designed in which each type of aggregate was exposed to several times of mixing to evaluate possible changes to the grading curves and in the surface of the aggregates grains. Moreover, four types of concretes were designed (two with barite, one with EAF slag aggregate and one with conventional limestone aggregate) to evaluate the repercussion of this phenomenon on the fresh and hardened state properties. The results show that the mixing process modifies the grading curve of the barite at a higher extent than in the case of the other aggregates. This also has repercussion in the properties of concrete, which shows increased workability as well as poorer compressive strength and elastic modulus. The observations from the study help to explain this behavior and provide important guidelines for the design, the production and the use of barite as an aggregate for concrete [9]. The use of Tunisian barite powder form in the composition of concrete was investigated, substituting sand partially or totally by Saidani et al. (2015). Investigation was carried out on five groups of concrete samples with density (2.31–2.48) corresponding to the mass of barite's percentages ranging from 0% to 25%. The effect of barite ratio on the physical and mechanical properties such as compressive strength, tensile strength, density, shrinkage, swelling, and elastic modulus have been measured and compared to ordinary concrete as a control. The tensile strength has been reduced up to 50%, the compressive strength at 28 days has decreased only by 10% and the elastic modulus at one year of age by 20% [10]. Jankovic et al. in 2016 investigated the effect of Nano-silica replacement of cement (2% or 5%) and aggregate type (quartz, barite or its combination 50:50 by volume) on the properties of ultra-high performance concrete (UHPC). They concluded that UHPC with Nano-silica and combination of barite and quartz aggregate is composite which has finer pore-size distribution, improvement in compressive and flexural strength and in radiation protection characteristics, with potential usage as building material for hospitals and nuclear facilities [11]. In 2017, Hayrullah et al. studied four different mineral additives contains barite, colemanite, basaltic pumice and ground granulated blast furnace slag (BFS). Each mineral additive was used one by one and binary, ternary and quaternary combinations. Utilization of these mineral additives as fine aggregates and cement replacement material was investigated and the effect of these materials on compressive strength, splitting tensile strength, ultrasonic sound velocity, capillary water absorption and abrasion resistance were examined. According to the analysis, it was seen that blast furnace slag and colemanite were the two most effective parameters on results in general [12]. Arel et al (2017) studied the physical and chemical attack of reinforced concrete structures in nuclear power plants (NPPs) throughout their service life. Based on the data available, it can be inferred that barite aggregate can be used to improve performance in NPP components that may be exposed to radiation, fly ash can be added to decrease hydration temperatures, and low C3A content cement and low water-to-cement ratios can be used to increase resistance to sulphate attack[13]. The effect of barite on concrete was studied by several other researchers, Kilincarslan (2006), Gokce (2018), shams (2018) and Liu(2019) [14-17]. According to the performed researches, it was found that the use of barite aggregate in the production of heavy concrete resulted to achieve the protection characteristics required for heavy concrete, but it influences mechanical properties of the concrete and reduces the mechanical properties of the concrete. On the other hand, nanotechnology is one of the sciences that have been considered in recent years, which has made significant progress in the production of new materials and stuff with much improved properties. Nano-scale means dimensions from 1nm to 100nm. The first spark of nanotechnology (although it was not yet known at that time) was described by Richard Feynman in 1959 [18] during a lecture with the subject that in the near future molecules and atoms could be manipulated directly. The term "nanotechnology" was first used in 1974 by Norwin Tayen Guchi [19], professor of Tokyo Sciences University. He used this term to describe the production of precision materials which their dimensional tolerance is in the nanometer range. In 1986, the term was revised and redefined by K. Eric Drexler in a book titled " Engines of Creation: The Coming Era of Nanotechnology" [20]. He studied this term in a deeper way in his doctoral dissertation and later developed it in a book entitled " Nano systems: Molecular Machinery, Manufacturing, and Computation" [21]. Along with the use of Nano-scale materials in various sciences, the replacement of concrete additives with samples containing Nano-materials has been highly regarded and significantly improved the mechanical properties of concrete. The effect of Nano powder on concrete was studied by several researchers, Heidari and Tavakoli (2013), Senhadji et al. (2014), Ruan et al. (2018), Wang et al. (2018), Sun and Chen (2018), Han and Zhang (2018), Li et al. (2019), Hamed et al. (2019), Norhasri et al. (2019), Tobbala (2019)[22-31].

Therefore, in this research, in order to evaluate the effect of using Nano-barite on mechanical properties of concrete, weight percentages of Nano-barite with combined cement and compressive strength of concrete were measured at different times to obtain the best percentage of additive and mixing design.

MATERIALS AND METHODS

The purpose of this research is to produce concrete using Nano barite instead of barite aggregates, in addition to achieving the required protective features in heavy concrete, mechanical properties of concrete are also kept with the minimum defect. For this purpose, various samples of concrete have been made, which the only variable in the used materials is the percentage of Nano barite added to the materials. Therefore, the effect of the percentage of added Nano-barite to concrete, on increasing or decreasing the compressive strength of the concrete will be determined in his research by preparing concrete experimental mixed designs with compressive strength ranges of C15, C25 and C40, and replacement of different values of Nano barite from 1% to 9% of cement weight and comparing their compressive strengths with the blank sample in a completely equal condition. Nano barite powder and samples of concrete are displayed in Fig. 1. One of the most important parameters that should be considered in the production of concrete is the type and percentage of aggregates consumed in the concrete mixing design. For this purpose, the ASTM C33/C33M, C637 and C638 standard guidelines have been used as the aggregation acceptance criterion in the mixing design used in this study [3, 4, 32]. The aggregation used in this study is shown in Table (1). One of the most important things to consider when designing concrete samples containing Nano-barite is how to add Nano-barite to materials prepared for concrete production. The results cannot be cited if the Nano barite is not completely homogeneous in the total mixture of aggregate materials. In this research, in order to achieve this, we first weigh the amount of Nano-barite and cement required by the percentage determined in the mixing design and pours it into a container and mix with a magnetic stirrer for 3 minutes until the homogeneity of cement and Nano barite. Then, the amount of aggregate materials based on the aggregation determined in the concrete mixing design is poured from the larger size inside the mixer, respectively, and then the homogeneous powder of cement and pre-prepared Nano barite is added to the mixer, and the aggregate and concrete materials are mixed together for 3 minutes in a mixer to distribute the cement and Nano barite homogeneously among the aggregate materials.

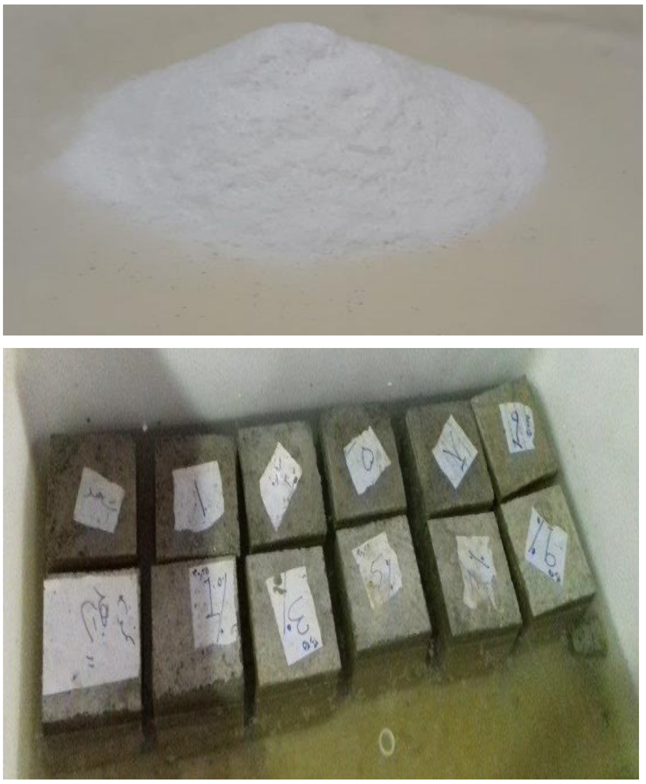

FIGURE 1. NANO BARITE POWDER (TOP) AND SAMPLES OF CONCRETE (DOWN)

Finally, the amount of water determined in the mixing design is added to the aggregates in the mixer and aggregates and water are mixed together for 1 minute. After mixing the materials with each other, the concrete is poured into cube molds of 15 * 15 * 15 cm that are pre-prepared and lubricated. According to the ASTM C31/C31M standard [33], prepared concrete samples were maintained in a mold and in the range temperature of 20 to 30 °C and the relative humidity of 55-50% and transferred to the laboratory within 24 ± 8 hours and after removing them from the mold, they are stored until the day of compressive strength test in a standard curing pond at a temperature of 23±1.7 ° C which has been saturated with lime. It is necessary to mention that all of compression tests done by compression testing machine with loading velocity of 50 to 2000 Kg/s and nominal capacity of 200 tons that made by soil mechanics industries(according to the ASTM C39/ C39M Standard [34]) (See Fig. 2).

Table 1: Aggregating the used materials in the production of concrete samples

Sieve size (mm)	Sieve number	Passing weight percent
9.5	[illegible]in	100
4.75	4	100
2.36	8	75.8
1.18	16	51.9
0.6	30	31.2
0.3	50	15.9
0.15	100	4.5

FIGURE 2. COMPRESSION TEST

RESULTS AND DISCUSSION

The experimental results regarding the determination of compressive strength of concrete containing different percentages of Nano barite indicate that the presence of Nano barite in concrete does not necessarily increase or decrease the compressive strength of concrete, and both increase or decrease states of compressive strength can occur based on the percentage of Nano barite added to concrete. The compressive strength and compressive stress changes for three concrete strength grades of C15, C25 and C40 are shown in the Table 2 and Fig. 3.

Table 2: Pressure force applied to blank sample and concretes with a different amounts than Nano barite at the age of 28 days

Concret e type	Blank sample	1%	3%	5%	7%	9%
C15	34200	3290 0	3720 0	4420 0	4150 0	3830 0
C25	57240	5256 0	5622 0	6336 0	5892 0	5514 0
C40	89550	8170 0	8440 0	9425 0	9015 0	8270 0

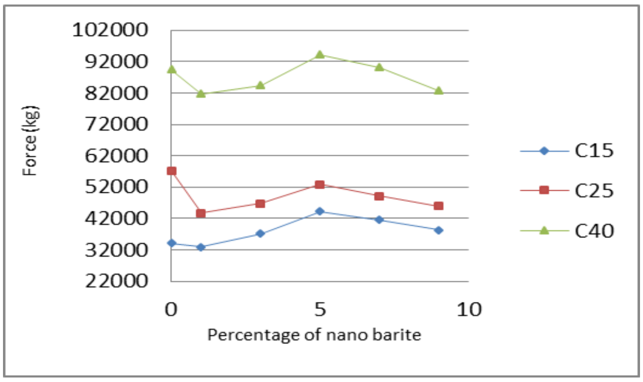

FIGURE 3: Comparison of applied compressive strength to different strengths range of concretes at the age of 28 days

With regard to Fig. 3, it can be seen that the higher the resistance grade of the concrete, the more compressive force can be tolerated, which is quite logical. Also, the variation of the tolerable force gradient in each of the three resistance classes is roughly the same, indicating that the addition of Nano-barite to concrete, independent of the concrete strength grade, is affected and its changes are predictable. In all strength grades of concrete, by adding 1% Nano barite to concrete, the amount of tolerable compressive force was reduced by the samples. By increasing the percentage of Nano barite up to 5%, the applied compressive force was upward and by increasing the percentage of Nano barite, the tolerable compressive force of samples is downtrend. In this way, it can be concluded that the best percentage of adding Nano-barite to concrete is 5% by weight of cement and increasing or decreasing this percentage reduces the strength of concrete against compressive forces. The concept of compressive stress applied to concrete is used to better understand the effect of adding Nano barite on concrete. According to the dimensions of concrete samples, which are 15 * 15 * 15 cubic centimeters, the amount of tolerable vertical stress that is obtained by dividing the tolerable compressive force by 225, at kg/cm2 will be as Table 3 and Figs. 4 to 7.

Table 3: Compressive stress of blank sample and other concretes with a different grade than Nano barite at the age of 28 days

Concrete type	Control	1%	3%	5%	7%	9%
C15	152	146.22	165.33	196.44	184.44	170.22
C25	254.4	233.6	249.86	281.60	261.86	245.06
C40	398	363.11	375.11	418.88	400.66	367.55

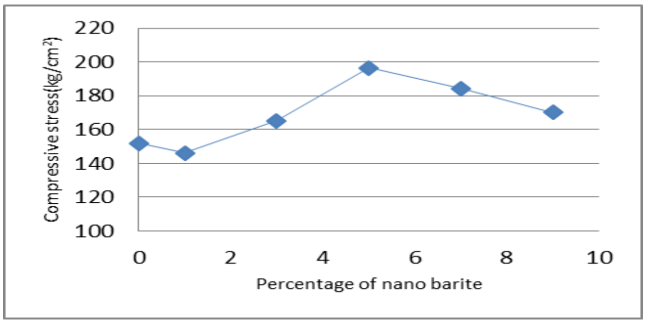

FIGURE 4: compressive stress of C15 concrete with a different grade than Nano barite at the age of 28 days

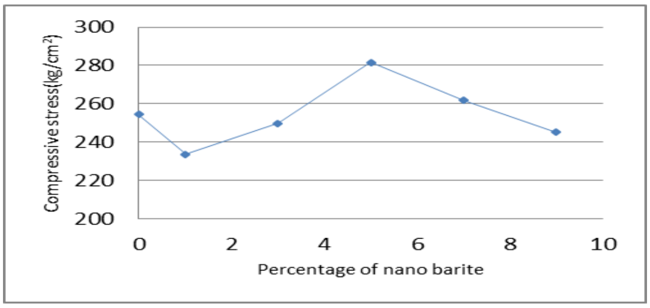

FIGURE 5: compressive stress of C25 concrete with a different grade than Nano barite at the age of 28 days

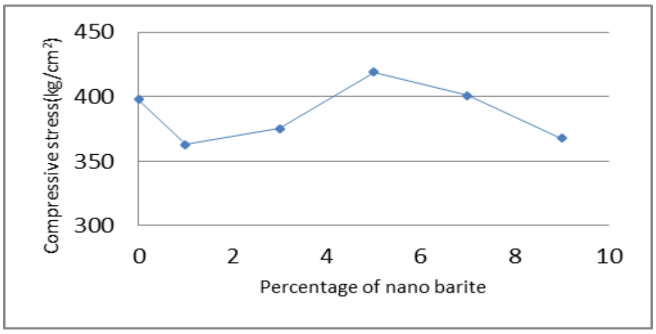

FIGURE 6: compressive stress of C40 concrete with a different grade than Nano barite at the age of 28 days

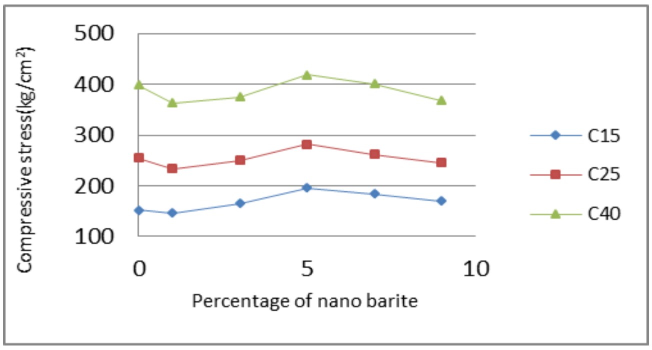

FIGURE 7: Comparison of compressive stress applied to concretes with different compressive strength

It is observed that by adding different percentages of Nano-barite to concrete samples with different strength classes, there is no significant change in the compressive strength of the samples and the obtained concrete, in addition to having heavy concrete specification, can also be used as a structural concrete. The highest amount of compressive strength loss of concrete in this study was in the case of adding Nano barite by 1% of cement weight and by increasing the percentage of Nano-barite to 5%, the compressive strength of concrete had a rising trend. In this percentage, concrete strength slightly increases compared to the control sample, by increasing the percentage of Nano barite by more than 5%, the compressive strength of the concrete decreases with a very gentle gradient. This compressive strength variation process is affected by two factors: (1) According to Fig. 8, concrete slump increases by increasing the percentage of replacement of Nano-barite instead of cement. In other words, by adding Nano-barite to concrete, the concrete performance is increased and the amount of water required for the concrete production is reduced, which increases the strength of the concrete. On the other hand, Nano-barite acts as a filler material, which causes the porosity in the concrete to be filled and becomes denser, which increases the compressive strength of the concrete. However, with an increase of more than 5% of this material, due to the reduction of cement content as concrete binder, the compressive strength of the concrete, despite the decrease of porosity, will find a downward trend. (2), on the other hand, by increasing the substitution percentage of Nano barite instead of cement, due to the decreasing of mortar cement, the compressive strength of the concrete decreases, despite decreasing the amount of water in the mixing design. In addition, in percentage of more than 5%, the percentage of water and cement decreases simultaneously in the concrete mixing design, as a result, the ratio of water to cement (W/C) is almost constant, which alone will not have an effect on increasing the compressive strength of the concrete.

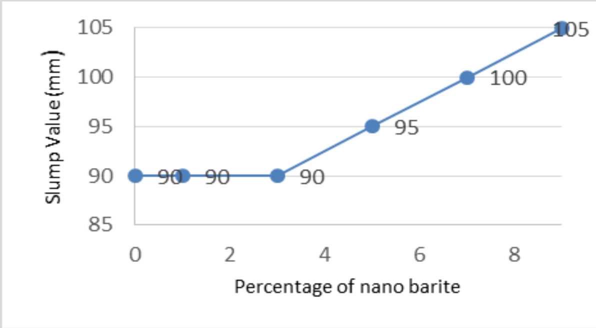

FIGURE 8: Relation between slump and the percentage of Nano barite used for concrete

The highest percentage of strength increase was observed in C15 concrete with 29% increase and its lowest increase value was observed in C40 concrete with 5% increase in strength. This increase in strength in C25 concrete was by 11%. Also, the lowest strength was observed in C15 concrete with 4% and the highest reduction was observed in C40 concrete with a strength decrease of 9%, which was 8% in C25 concrete. Therefore, it can be concluded that in the lower the strength grade of the concrete, the addition of Nano-barite to it leads to more increase of the strength compared to concretes with high-grade strength. Also, in the lower the strength grade of the concrete, the addition of more than 5% or less than 3% of Nano-barite to the concrete will have less effect on the reduction of the compressive strength of the concrete, which this decrease in the compressive strength of concrete will be increase by increasing the strength grade of concrete. In other words, the addition of Nano-barite to lower-grade concrete has more positive effects and its negative effects can be neglected on concrete strength. But this process is the opposite of high strength grade concrete and should be taken into consideration.

CONCLUSION

The mechanical properties of concrete produced by Nano barite have been evaluated in this research. According to the experiments carried out in this study, the following results can be presented:

- In concrete made by Nano barite, in addition to having heavy concrete specifications, no significant negative changes have occurred in the mechanical properties of concrete, which indicates the applicability of this type of concrete, as a structural concrete.

- By increasing the strength grade of concrete, the negative effects of adding the Nano barite on the compressive strength of concrete are more than those with less strength classes. This trend is reversed in relation to the increase of concrete strength, so the lower the concrete strength class, has the higher increase percentage of strength compared to the control sample. Therefore, in the case of the addition of Nano barite to low strength grade concrete, the compressive strength loss is not appreciable, but in concrete with high strength class, concrete mechanical properties tests should be done more carefully.

- In this research, the highest compressive strength loss of concrete was observed in the addition of Nano barite by 1% to weight of cement and by increasing the percentage of Nano barite to 5%, the compressive strength of concrete had a rising trend. In this percentage, the strength of concrete increase compared to the control sample. By increasing the percentage of Nano barite by more than 5%, the compressive strength of the concrete will be reduced with a very gentle gradient.

- The highest percentage of strength increase was observed in C15 concrete with 29% increase and its lowest value was in C40 concrete with 5% increase in strength. The lowest strength decrease was observed in C15 concrete with 4% and the highest reduction in C40 concrete with a strength decrease of about 9%.

- By evaluating the results of the slump test, it can be seen that with the addition of Nano barite to 3% by weight of cement, the performance of the concrete has not changed, and then, by increasing Nano barite percentage, the performance of the concrete increases, so adding 9% of Nano barite, will lead to 17% increase in the concrete's performance, which can reduce the amount of water used in the production of concrete samples and increase its compressive strength.

- using Nano materials instead of traditional materials cause to reduce size of concrete samples that it reduces cement and aggregates consumption and harms the environment.

References

[1] Neville, A. M.; Brooks, J.J., " *Concrete Technology (2nd Edition)*", Pearson education Publication, 2010, UK.

[2] *ACI 304.3R-96, Heavyweight Concrete:* Measuring, Mixing, Transporting, and Placing, American Concrete Institute, 1996.

[3] *ASTM C637-14, Standard Specification for Aggregates for Radiation-Shielding Concrete*, ASTM International, West Conshohocken, PA, 2014.

[4] *ASTM C638-14, Standard Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete,* ASTM International, West Conshohocken, PA, 2014.

[5] Topcu I., Properties of heavyweight concrete produced with barite, *Cement and Concrete Research journal*, Volume 33, Issue 6, 815-822, 2003.

[6] Akkurt. I, Basyigit. C, Akkas. A, Kilincarslan. S, Gunoglu. K, "Photon attenuation coefficients of concrete includes barite in different rate", *Annals of Nuclear Energy journal*, 37, 910-914, 2010.

[7] Akkurt I, Basyigit C, Akkas A, Kilincarslan S, Mavi B, Gunoglu K., "Determination of Some Heavyweight Aggregate Half Value Layer Thickness Used for Radiation Shielding," in Proceedings of the *International Congress on Advances in Applied Physics and Materials Science*, Antalya, 2012.

[8] Vahidnia A., Naseri H., Investigation of Physical and Mechanical Properties of Heavy Concrete with Barite Gradation, *First National Conference on Concrete Industry*, 2012, Iran.

[9] González-Ortega M. A., Cavalaro S.H.P., Aguado A., Influence of barite aggregate friability on mixing process and mechanical properties of concrete, *Construction and Building Materials*, Vol 74, 169-175, 2015.

[10] Saidani K., Ajam L., Ouezdou M. B., Barite powder as sand substitution in concrete: Effect on some mechanical properties, *Construction and Building Materials*, Vol 95, 287-295, 2015.

[11] Jankovic K., et al., The influence of Nano-silica and barite aggregate on properties of ultra high performance concrete, *Construction and Building Materials*, Vol 126, 147-156, 2016.

[12] Sevinc A. H., Durgun M. Y., Eken M., A Taguchi approach for investigating the engineering properties of concretes incorporating barite, colemanite, basaltic pumice and ground blast furnace slag, *Construction and Building Materials*, Vol 135, 343-351, 2017.

[13] H. S. Arel., E. Aydin., S. D.Kore., Ageing management and life extension of concrete in nuclear power plants, *Powder Technology*, Vol 321, 390-408, 2017.

[14] Kilincarslan S., Akkurt I., Basyigit C., The effect of barite rate on some physical and mechanical properties of concrete, *Materials Science and Engineering*: A, Vol 424, Issues 1–2, 83-86, 2006.

[15] Gokce H. S., Yalcinkaya C., Tuyan M., Optimization of reactive powder concrete by means of barite aggregate for both neutrons and gamma rays, *Construction and Building Materials*, Vol 189, 470-477, 2018.

[16] Shams T., Eftekhar M., Shirani A., Investigation of gamma radiation attenuation in heavy concrete shields containing hematite and barite aggregates in multi-layered and mixed forms, *Construction and Building Materials*, Vol 182, 35-42, 2018.

[17] Liu H et al., An investigation on physical, mechanical, leaching and radiation shielding behaviors of barite concrete containing recycled cathode ray tube funnel glass aggregate, *Construction and Building Materials*, Vol 201, 818-827, 2019.

[18] R. P. Feynman, R. B. Leighton, M. Sands, *The Feynman Lectures on Physics*, three volumes, (1963, 1964, 1965), Basic Books Publication, 2011.

[18] Taniguchi, N., On the Basic Concept of Nanotechnology, Proceedings of the *International Conference on Production Engineering*, Tokyo, 18-23, 1974.

[20] Drexler, K. E, *Engines of Creation: The Coming Era of Nanotechnology*, Doubleday, 299p, 1986.

[21] Drexler, K. E, Nanosystems: *Molecular Machinery, Manufacturing, and Computation*, John Wiley & Sons, 1992.

[22] Heidari A., Tavakoli D., A study of the mechanical properties of ground ceramic powder concrete incorporating nano-SiO2 particles, *Construction and Building Materials*, Vol 38, 255-264, 2013.

[23] Y. Senhadji et al., Influence of natural pozzolan, silica fume and limestone fine on strength, acid resistance and microstructure of mortar, *Powder Technology*, Vol 254, 314-323, 2014.

[24] Ruan Y et al., Carbon nanotubes reinforced reactive powder concrete, *Composites Part A: Applied Science and Manufacturing*, Vol 112, 371-382, 2018.

[25] Wang H et al., Multi-functional properties of carbon nanofiber reinforced reactive powder concrete, *Construction and Building Materials*, Vol 187, 699-707, 2018.

[26] J. Sun., Z. Chen., Influences of limestone powder on the resistance of concretes to the chloride ion penetration and sulfate attack, *Powder Technology*, Vol 338, 725-733, 2018.

[27] F. Han., Z. Zhang., Properties of 5-year-old concrete containing steel slag powder, *Powder Technology*, Vol 334, 27-35, 2018.

[28] L. G. Li et al., Filler technology of adding granite dust to reduce cement content and increase strength of mortar, Powder Technology, Vol 342, 388-396, 2019.

[29] Hamed. N et al., Effect of Nano-clay de-agglomeration on mechanical properties of concrete, *Construction and Building Materials*, Vol 205, 245-256, 2019.

[30] Norhasri. M. S. M., Hamidah. M. S., Fadzil A. M., Inclusion of Nano metaclayed as additive in ultra-high performance concrete (UHPC), *Construction and Building Materials,* Vol 201, 590-598, 2019.

[31] Tobbala. D. E., Effect of Nano-ferrite addition on mechanical properties and gamma ray attenuation coefficient of steel fiber reinforced heavy weight concrete, *Construction and Building Materials*, Vol 207, 48-58, 2019.

[32] *ASTM C33/ C33M-18, Standard Specification for Concrete Aggregates, ASTM International*, West Conshohocken, PA, 2018.

[33] *ASTM C31/ C31M-18b, Standard Practice for Making and Curing Concrete Test Specimens in the Field*, ASTM International, West Conshohocken, PA, 2018.

[34] *ASTM C39 / C39M-18, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*, ASTM International, West Conshohocken, PA, 2018.