# Novel Method for Radiation Shielding Using Nano-Concrete Composite

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***Abstract*—In the event of nuclear bomb most of our shelters don't stop nuclear radiation. Higher density concrete is sometimes used. The use of high-density concrete decreases the required thickness of the concrete barrier; hence, its disadvantage is its high cost. Hence by mixing up of galena (Pbs) and some kinds of nano particles with concrete at suitable mix proportion is useful to block the impact of radiation. Materials and method: galena (PbS) mineral was used to produce of a high-density concrete. And the nano particles such as silica nano particles and carbon nanotubes are used. Two types of concrete mixes were produced. The water-to-concrete (w/c) ratios of the reference and galena concrete mixes were 0.53 and 0.25, respectively. Conclusion: The nano concrete with the composite of galena, nano concrete samples made in laboratories had showed good shielding/engineering properties in comparison with all samples made by using high-density materials other than depleted uranium. Results:The galena mineral along with nano silica and carbon nanotubes used in this study had a density of 7400 kg/m3. The concrete samples had a density of 4800 kg/m3. Furthermore, the nano concrete samples had significantly higher compressive strength (500 kg/cm2 compared to 300 kg/cm2).**

***Index Terms*—high density concrete, galena, shielding, lead dry wall, nano silica, carbon nano tubes**

## I. Introduction

Concrete, composed of Portland cement, sand, aggregate (stones, gravel, etc.), and water [1], is one of the most common materials used in the construction of commercial buildings. Its properties make concrete an excellent choice for structures, cladding systems and floor slabs. On the other hand, concrete is widely used for radiation shielding in radiotherapy facilities and nuclear reactors, and for the prevention of radiation leakage from radioactive sources, as well. Although, aggregate has been basically considered as an inert, inexpensive material, it is not truly inert and influences the performance of the concrete due to its physical and sometimes chemical properties [2]. Concrete is a very strong material when compressed. However, it is extremely weak in tension. The strength and other properties of concrete are dependent on how the above-mentioned four ingredients are proportioned and mixed. The maximum resistance that a concrete structure will sustain, when loaded axially in compression in a testing machine at a specified rate, is measured as the compressive strength. sometimes higher density concrete such as barite (density up to about 3500 kg/m3) are sometimes used, as well.in case of A nuclear reactor usually it requires two shields: a shield to protect the walls of the reactor from radiation damage and at reflect neutrons back into the core the same time; and a biological shield used to protect people and the environment. The biological shield consists of many centimeters of very high-density concrete. In nuclear reactors, neutron radiation is the most difficult to shield. Hydrogen is the most effective element in slowing down (thermalizing) neutrons over the entire energy spectrum. Boron is effective in capturing thermal neutrons and it releases alpha particles which are easily shielded [3]. In a nuclear reactor, as with other radiation fields, the main problem in selecting the shielding materials, is to choose the most efficient and economical shield against all existing radiations in the field. Concrete is an economical and effective material for shielding stationary reactors. As high-density materials are needed to be shielded against gamma rays, a high-density concrete is often preferred to the low density type. High-density concrete has higher linear gamma and neutron attenuation characteristics in comparison with ordinary the concrete; therefore, the use of high-density concrete leads to thinner walls. Neutron radiation is the most difficult to shield. Galena (PbS) is the main lead mineral [4]. Other common varieties include cerussite ($PbCO_3$), plattnerite ($PbO_2$) and anglesite ($PbSO_4$). Galena is a Latin word given to lead ore or the dross from the melted lead. Galena with a density of 7400-7600 kg/m$^3$ material, is almost as dense as iron. Galena is the most important ore mineral of lead. Its structure is identical to that of halite, NaCl. The two minerals have the same crystal shapes, symmetry and cleavage. The molecular weight is 239.27 g and the ideal composition is 86.6% lead and 13.4% sulfur. Some galena may contain up to 1% silver in place of lead. The large volume of galena that is processed for lead produces enough silver as a byproduct

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to make galena the leading ore of silver. The chemical composition and physical properties of galena are summarized in Table I.

TABLE I. THE CHEMICAL AND PHYSICAL PROPERTIES OF GALENA

| Chemical Composition | Lead Sulfide (PbS) |
|---|---|
| Molecular Weight | 239.26 g |
| Lead Content | 86.59 % Pb |
| | 13.40 % S |
| Hardness | 2.5 |
| Specific gravity | 7.6 |
| Color | lead-gray |

### A. *Lead Dry Wall*

Lead drywall is laminated with sheet lead that is designed to cover necessary surfaces or walls in a room requiring radiation shielding. It is affixed to surfaces or walls ensuring a continuous layer of sheet lead under the drywall to a specified height. It is used in new construction or shielding upgrades/renovations for diagnostic imaging rooms.

### B. *Lead Linings in Floors and Ceilings*

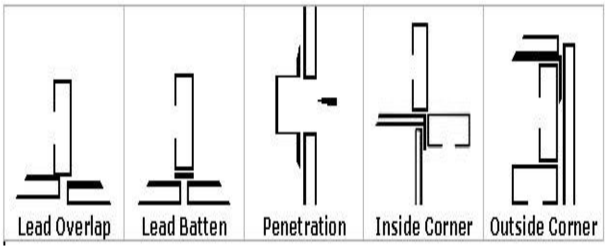


Figure 1. Typical details for thin lined lead wall.

In certain situations, the floor and/or ceiling of an x-ray room may require lead shielding and it is recommended to lay the lead in the floor before the final floor is poured. All joints should have a minimum of one-inch overlap. The lead should extend up each wall a minimum of two inches. Additional concrete can be applied over the lead finishing. If lead is required in the floor of an existing facility, it is recommended to install the lead in the ceiling of the room below. Securing lead to existing concrete presents problems with attaching, protecting, and covering the lead. Ceiling lead is installed by laying 16 inch by 49 inch sheets of rolled lead on top of lead filled channels suspended from the structure above. Once again, one-inch overlap is required at each joint. A standard acoustical ceiling can be installed under the lead lined ceiling. It is illustrated in the Fig. 1.

## II. MATERIALS AND METHODS

The concrete mix design was selected according to basic protocols of the study. Two types of concrete mixes were produced. Reference concrete mixes consisted of sand (945 kg/m$^3$), filler (214 kg/m$^3$), cement (920 kg/m$^3$), and water (180 kg/m$^3$ ). The water-to-concrete (w/c) ratio was 0.53. In the galena sample, 1300 g of galena mineral was used to replace sand completely in a total of 1811 g concrete

### A. *Additives in Concrete*

Better physical and mechanical characteristics of concretes and mortars could be achieved by different chemical additives such as antifreezes, super plasticizers, acryl, polypropylene, and glass, steel and other fibers and polystyrene beads. Some of these compounds are used in construction of residential buildings. Generally, additives are most often composed of a variety of different molecules which formulas are frequently unknown and protected for proprietary reasons .Consequently, for example impact of additives on radionuclides solubility in concrete is actually unknown which is significant information considering application of fly ash in its production. Additionally, there is no data on measurements whether any of additives in concretes or mortars evaporate due to wall heating, ageing or drilling. Despite the fact that polystyrene beads are in application for concrete production it seems that the major source of styrene emission are polystyrene pads used for insulating under the final floor covering and in walls. There are some aspects of air quality control on which there is very little data such as possibility of elimination of ammonia levels in indoor air by extra drying of concrete in which urea-based antifreeze substance are added .Levels of 0.11 ppm measured in such buildings

## III. RESULTS

The galena concrete made with nano silica, cnt and galena mineral used in the study had a density of 7400 kg/m$^3$. The concrete samples made in this project had a density of 4800 kg/m$^3$ in comparison to that of ordinary concrete (2350 kg/m$^3$) or barite high-density concrete (up to 3500 kg/m$^3$). The measured half value layer (HVL) thickness of Nano concrete samples for cobalt-60 gamma rays (1.25 MeV) was much less than that of ordinary concrete (2.6 cm compared to 6.0 cm). Furthermore, nano concrete samples had a significantly higher compressive strength (500 kg/cm$^2$ compared to 300 kg/cm$^2$). The comparison of engineering/shielding properties of Nano concrete samples to those of ordinary concrete are presented in Table II.

TABLE II. NI: NOT INDICATED BY THE AUTHORS

| types | Density ($kg/m^3$) | HVL for 1.25 MeV Energy Gamma Radiation (cm) | Compression Strength ($kg/m^2$) |
|---|---|---|---|
| Ordinary Concrete | 2500 | 5.25-6.2 | 300 |
| Barite Concrete (11) | 3180-3550 | 3.6-4.0 | 140-394 |
| Barite Concrete (12) | 3490 | 3.8 | NI |
| Barite Concrete (13) | NI | 4.4 | NI |
| Super Heavy Concrete (10) | 3800-4200 | NI | NI |
| nano Concrete | 4200-4600 | 2.56 | 500 |

## IV. DISCUSSIONS

Concrete samples made of Nano particles showed a significantly better performance in radiation shielding, and compressive strength in comparison to ordinary concrete. Based on the preliminary results obtained, Nano concrete showed to be a highly suitable option where high-density concrete is required in the event of nuclear fallout or explosion. It should be noted that the most common material for shielding the radiation from particle accelerators has been concrete. As mentioned, concrete could be made using various materials of different densities as aggregates. These different concrete mixes can have very different attenuation characteristics [5]. Kan *et al.* (2004) [6] added iron ore to concrete. They found that the compressive strength of heavy concrete increased with iron ore content, while the tensile strength declined. In their study, the concrete including 40% metallic aggregate content and the volume showed higher compressive strength and fracture toughness. It is also possible to increase efficiency, specific characteristics and safety of metal-concrete casks (shielding materials for casks used for spent nuclear fuel transportation and storage) by the use of highly dense depleted uranium dioxide (UO2) into concrete composition [7].

The Nano concrete samples made in this study showed a good shielding/engineering properties comparing to all the other samples made by high-density materials other than depleted uranium (DU). Considering the possible hazards of DU, it can be claimed that the Nano concrete can be a substitute non-radioactive shield for applications such as shielding megavoltage radiotherapy rooms. To highlight the importance of Nano concrete in shielding, its properties can be compared with to the heavy-concrete samples for which specifications have been reported in some recent publications.

In 2005, in an attempt to produce heavy concrete for protection against radiation, Proshin *et al.* produced concretes with densities of 3800-4200 $kg/m^3$, which the authors have called "Super heavy High-Strength concrete"[8]. They used waste products of heavy silicate-lead glasses. Bouzarjomehri *et al.* [9] produced heavy concrete samples using barite mineral. The samples they made had densities in the range 3180-3550 $kg/m^3$. The measured HVL for 1.25 MeV energy gamma radiation and compressive strength of their samples were 3.6-4.0 cm and 140-394 $kg/m^2$, respectively. Therefore, results obtained in the study indicate better physical properties of the reported high density concrete in comparison with those reported by other investigators.

## V. CONCLUSION

Hence by using the nano particles like carbon nanotubes and polycarboxylates along with Galena (Pbs) main lead mineral, a new type of concrete called nano concrete is made, which is used for preventing radiation in radioactive zones.

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