THE INNOVATIVE USE OF MODIFIED HIGH DESITY MICRO-CONCRETE FOR RADIATION SHIELDING & ATTENUATION

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Any sound concrete, in sections of sufficient thickness, can be used to construct a satisfactory biological shield, and where space is not a consideration, conventional concrete still appears to be the most satisfactory shielding material from the standpoint of cost. However, in many applications, space is a definite consideration. It is for these applications that research on the development and use of high-density concrete has been done. In such cases it is not possible to place the desired amount of normal weight concrete in the given space, hence, to provide adequate shielding, high density concrete is used. Since the ability of a radiation shield to attenuate alpha, beta, gamma, neutron, and proton particles is almost directly proportional to the density of the shield, attempts have been made to develop a concrete of maximum density using various heavy aggregates. High density aggregates are the key ingredient in high density concrete. Heavy density concrete or High Density concrete is concrete that has a density greater than 2402 Kg/m^3 upto a density of 5606 Kg/m^3. [1]

The density of high density concrete is based on the specific gravity of the aggregate and properties of the other components of concrete. The aggregates and other components are based upon the exact application of the high density concrete. Some of the natural minerals used as aggregates in high density concrete are hematite, magnetite, limonite, barite and some of the artificial aggregates include materials like steel punchings & shot. Minerals like bauxite, hydrous iron ore or serpentine, all slightly heavier than normal weight concrete can be used in case high fixed water content is required**.** It is essential that heavy weight aggregates are inert with respect to alkalis and free of oil and foreign coatings which may have undesired effects on bonding of the paste to the aggregate particles or on cement hydration.

There is a broad variation in the components used in High Density concrete based on the application. [2] For example, High Density Concrete used in Neutron Shielding has a high cement content to increase the percentage of hydrated water and aggregates like hydrous ores. Although this particular composition of high density concrete is lighter than normal weight concrete, it is very effective in neutron shielding as it has high hydrogen content.

The criteria used in selection of an aggregate are: intended use, physical properties, availability and economics. For radiation shielding, it is important to determine which trace elements may potentially become reactive when exposed to radiation. When selecting an aggregate for a specified density, the specific gravity of the fine aggregate should be comparable with that of the coarse aggregate through the mortar matrix. In case of ferro-phosphorous and ferrosilicon, they should only be used after ensuring suitability of laboratory mixtures since hydrogen evolution has been known to trigger a self limiting reaction that produces 25 times its volume of hydrogen. Antifoam agents can help reduce the entrapped air.

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During batching and mixing it is important to avoid over-mixing due to the fragility of certain aggregates. Contamination of the heavy weight aggregates with normal weight aggregates should be avoided by purging all aggregate handling and batching equipment, including pre-mixers and truck mixers.[4] Accuracy and condition of conveying and scale equipment, aggregate storage and concrete batching bins is especially important, since it is necessary to weigh the aggregates accurately to maintain water cement ratio and check fresh density frequently. Due to the high loads on the mixing equipment it is advisable to avoid overloading the mixers and conveying equipment; and starting and stopping while loading mixers. Forms and pumps must be designed keeping in mind the higher than normal densities of the aggregates and consequently the concrete. To prevent segregation of coarse aggregates the slump should be kept low and over-vibration avoided. Mortar may be placed in layers of specific thickness over which a fixed quantity of coarse aggregate may be placed and vibrated into the mortar. This is known as puddling.

There are no major differences between curing and protection procedures for normal weight and high density concrete. Below is a case study that explains how a specially formulated high density micro-concrete was used for the installation of a radiation unit at a hospital in India.

CASE STUDY: RADIATION ABSORBENT HIGH DENSITY MICRO-CONCRETE FOR THE FIRST EVER CYCLOTRON INSTALLATION AT TATA CANCER HOSPITAL, MUMBAI, INDIA

Problem:

Installation of Cyclotron radiation therapy unit at Tata Cancer Radiation Center, Mumbai in the basement.

In order to prevent the escape of radiation the specification prescribed by the **Atomic Energy Authorities** comprised an RCC wall at least 1700 mm thick with a density of atleast 2700 Kg/m^3 and modified with boron based radiation absorbing materials like columnite. Such concrete being of very high density lacks the required fluidity and workability and takes longer to set. While adding superplasticizers to such high density concrete would definitely make it workable and pumpable it would reduce the density of the concrete and thus completely defeat the original purpose.

Innovative Solution:

In this particular case, the key was to find a balance between workability and high density shielding properties. The aggregate typically used in such applications, is columnite, which absorbs radiation but has low density, per the specifications of the consultant and the Atomic Energy Authorities. [3]

From numerous trials, conducted by the R&D team at Sunanda Speciality Coatings Pvt. Ltd., was born a specially modified form of micro-concrete that had the high density as specified along with excellent workability and quick setting properties. The material was exhaustively tested in the Atomic Energy Department's laboratory and was then granted permission for use in this particular project. All the RCC members of the “Cyclotron” room were cast using this specially formulated micro-concrete and successfully satisfied all the requirements to prevent the escape of any radiation outside the room.

The team at Sunanda also advised the authorities on the effective pumping of this material. Although, the pumping device was not our in house development, it was only due to our thorough understanding of the material and its properties that we could suggest a suitable pumping device which could finally be used successfully.

<u>Properties of the specially formulated micro-concrete:</u>

Test Parameters:

Compressive Strength	(24hrs)	10 N/mm^2
	(3 Days)	20 N/mm^2
	(7 Days)	35 N/mm^2
	(28 Days)	50 N/mm^2
Flexural Strength	(28 Days)	15 N /mm^2
Tensile Strength	(28 Days)	10 N /mm^2
Young's Modulus		32 KN /mm^2
Unrestrained Expansion		1 to 4%
Fresh concrete Density		2700 kg/m3

<u>Highlights of the Project:</u>

1. The project was completed in a record time of 15 days.
2. The high density concrete being extremely user-friendly and workable and was poured from the most difficult places including the top of ceilings and walls.
3. Special strong and stable shuttering had to be designed to bear the weight and horizontal force exerted by such high density concrete.
4. Experts in the field of chemical engineering were invited to design the appropriate stirrer to mix this specially formulated high density micro-concrete and also to design the

special pumps which were used to pump this material from unusual positions and heights.

5. No honey combs and shrinkage cracks were formed on completion and curing of the concrete.

Conclusions:

1. This is a very cohesive material with an optimized composition of various high density aggregates along with the low density columnite, results in very high density concrete thus preserving radiation shielding & neutron shielding properties.
2. It has very good fluidity and pumpability while still maintaining properties of cohesion, strength, density, stability and hence can be poured from inconvenient locations such as heights, small gaps, crevices, ceilings, etc.
3. Most of the times in such precarious locations like the Cyclotron room it becomes almost impossible to vibrate concrete. The self leveling and self compacting properties of the micro-concrete completely do away with the need to vibrate the concrete and thus make it very convenient to pour high density concrete into inconvenient locations like basements where radiation emitting equipment is placed.
4. In the hardened state, it forms a non shrink material and hence crack-free which is very important for radiation proof concrete.
5. As this concrete is so dense, a great amount of heat of hydration is produced while the concrete is setting. Consequently, special ingredients have been added to this material to ensure negligible shrinkage cracks.
6. It has good bond strength, is compact and very dense and hence the formation of honeycombs is almost next to impossible. This makes it an excellent choice for applications like radiation proof concrete as the formation of honeycombs would render the walls susceptible to leakage of radiation.
7. Cures to form an excellent finished surface when in contact with the formwork.

Future Scope:

Based on the success at Tata Cancer Radiation Center, currently the R&D team at Sunanda are testing hematite based micro-concrete for a proposed radiation center at Holy Spirit Hospital in Mumbai. The density of this hematite based micro-concrete is close to 3300 Kg/m3.

References:

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3. SP 23 (S & T) 1982 – HANDBOOK ON CONCRETE MIXES, BUREAU OF INDIAN STANDARDS, NEW DELHI.

4. S.N.SIHNA, SIMPLIFIED METHOD FOR NORMAL CONCRETE MIX DESIGN, THE INDIAN CONCRETE JOURNAL, VOL.59, NO.6, JUNE 1985.

PICTURES FROM TATA CANCER RADIATION CENTER

MIXING OF MICRO-CONCRETE

PUMPING THE MICRO-CONCRETE TO FLOW TO A DEPTH OF 1700 MM FOR RADIATION CONTAINMENT