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Designing of a Radiographic Testing Room in an Industry and Its Safety Management

Hammadhu Rukiya Jalva H

M.E. Construction Engineering and Management, Department of Civil Engineering, R.V.S Technical Campus, Coimbatore, India

ABSTRACT: Civil engineering is a wide field involving construction of various structures which needs high attention to safety. Radiography technique is one of the most widely utilized non-destructive testing methods, used in industry to evaluate the structural integrity or to find out the hidden details of an assembled structure. Since this method uses ionizing radiation, it is important to ensure not only the quality of product but also the safety of technician, public around and environment. This paper involve designing of a radiographic testing room in an industry according to the standards prescribed in National Building Code (NBC) and Atomic Energy Regulatory Board(AERB).Planning of the room, designing of the elements and analysis of the structure has been done assuring prevention of hazards and accidents from harmful radiations. This paper also explains about the safety management and emergency plan to be implemented at the working site of radiographic testing room.

KEY WORDS: Radiographic Testing, ALARA, AERB, HVL, Exposure Limits,Dose Rate, Attenuation, Safety Management, Emergency Plan.

I.INTRODUCTION

Radiographic testing is a non-destructive testing(NDT) method which uses gamma radiation to check out the quality of product and detect the flaws. As radiations from radioactive material is highly hazardous, great importance has to be given for safety and health considerations. This paper involves the construction of a single RT room as a shielding to reduce the intensity of ionizing radiation exposed to workers and surrounding. Effectiveness of the shielding depends upon the thickness of material used, atomic number/density of the radioactive element used for the testing and energy of the radiation emitted by the element. The design should be sufficient to keep the dose rate within permissible limit and give a safe and secure environment to the workers. The radiation protection and safety objectives applies to the siting location, design, manufacture, or construction commissioning operation, maintenance and decommissioning of exposure devices, sealed sources and fixed facilities .

II.STUDY ON RADIOGRAPHIC TESTING

Industrial radiography may be carried out under variety of exposure conditions. For the purpose of design, exposure conditions are classified into three types of site: fully enclosed site, partially enclosed site and open site. We are going to design a fully enclosed site which uses radioactive elements like Cobalt (CO^{60}) and Iridium (Ir^{192}) as source to check the quality of the product.
Design of the room depends upon the type of radioactive source we are using and its effectiveness. The intensity of radiation and its effects can be calculated by using various methods.

A. Inverse Square Law:

The intensity of radiation received from any point source obeys inverse square law.

$$\mathbf{I_1 d_1^2 = I_2 d_2^2}$$

Where $\mathbf{I_1}$&$\mathbf{I_2}$ are intensities and $\mathbf{d_1}$ & $\mathbf{d_2}$are distance from the source respectively.

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TABLE 1
EFFECT OF RADIATION SOURCE IN CONCRETE

Source	Approximate concrete thickness	
	Minimum	Maximum
Co-60	125mm	500mm
Ir-192	25mm	250mm

B.Attenuation:

The absorption and scattering of some of photons of the radiation when it pass through the particle is called attenuation. The effect of attenuation can be calculated as below:

$$I = I_0 e^{\mu x}$$

I_0 = Initial intensity, μ = Linear attenuation coefficient per unit distance, x = Distance travelled through matter.

C.Half Value Layer:

The thickness of given material where 50% of radiation has been attenuated is called half value layer. It is expressed in distance (mm or cm).

$$HVL = 0.693/\mu$$

TABLE 2
HALF VALUE LAYER OF DIFFERENT MATERIALS

Half Value Layer (mm)					
Source	Concrete	Steel	Lead	Tungsten	Uranium
Iridium-192	44.5	12.7	4.8	3.3	2.8
Cobalt-60	60.5	21.6	12.5	7.9	6.9

Commonly used Gamma emitting radioactive nuclides and its effect on steel as given below in table:

TABLE 3
EFFECT OF RADIONUCLIDES ON STEEL

Radionuclides	γ Energies(MeV)	Half life	Optimum steel thickness (mm)
Co-60	High(1.17 & 1.3)	5.3 years	50-150
Ir-192	Medium (0.2 &1.4)	74 days	10-70

III. DESIGN CONSIDERATIONS FOR RT ROOM

1. A fully enclosed site shall be constructed with access doors or ports closed, the walls, floors and ceiling surrounding the site should be prevented from leakage of radiation.
2. The shielding should ensure that at no time during exposure the dose rate outside enclosure exceed 25 μSv/h measured 5 cm from any accessible surface and no member of public shall receive effective dose of 1 mSv/year.
3. Interlocks shall be fitted to all access points which will activate a visible and audible alarm if any interlock is opened during exposure.

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4. Doors and panels covering access apertures should overlap other apertures by a sufficient margin to prevent leakage of scattered radiation from the enclosure. Where maze is used for access of persons, a lockable door or barrier shall be incorporated and connected to an interlock.
5. Conduits for feeding cable including wind out cables, electrical power or other services through the walls shall incorporate dog-leg or baffle that leaves no line-of-sight aperture through walls to the radiation source.
6. Before constructing a fully enclosed site, plans and details of construction and of proposed operation shall be provide to statutory authority for approval.
7. Building materials used in radiation shielding are as follows:
    a. Lead sheet and lead fabricated products
    b. Concrete
    c. Barium plaster
    d. Gypsum wallboard
    e. Various types of bricks
    f. Lead glass

8. Lead has both high atomic number and high density (11530 kg/m^3) and hence very effective shielding Material.
9. Concrete and concrete blocks of high density (2350 kg/m^3) is a commonly used shielding material but normal concrete of 1:2:4 mix of increased thickness is sufficient for shielding.
10. Barium plaster of several coating up to 25mm thickness are applied for finishing and make the surface crack free.
11. Brick should be chosen carefully and the cavities in the bricks should be filled with mortar of at least same density.
12. Shielding is not necessary if there are no occupied basements and a thickness of 150mm is needed for load bearing and this will provide sufficient protection.
13. Doors and frame must be shielded against scatter with minimum 1.5 cm overlap.
14. Labyrinth design is effective in reducing the thickness of lead lining and reduces the radiation approximately to 0.1% for each scatter.

IV. RESULTS MADE FROM THE STUDY

1. Among the various radiation shielding materials like barium, metal foam, lead, atoms with high atomic number, lead provides more efficient and economic shielding. Hence lead is used as the lining inside the wall with a thickness of about 15mm.
2. Among the various types of cement and admixtures,it is found that M20 grade concrete mix of normal concrete with increased thickness is sufficient to prevent radiation exposure. Hence M20 grade concrete and Fe415 steel bars are adopted.
3. A labyrinth design of Reinforced Concrete wall of 300mm thickness and lead lining of 15mm thickness is checked for its ability to attenuate the radiation from Cobalt (CO^{60}) and Iridium (Ir^{192})source and the result is well satisfied and radiation exposure within permissible limit.
4. Ventilators are provided in V shape for attenuation of radiation.

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V.PLAN OF THE RT ROOM

The plan of the radiographic testing room has been made with auto CAD software and the elements were designed according to the codes from is IS code books.300 mm thickness is adopted for walls and a lead lining of 15mm is given to prevent the escape of radiation.

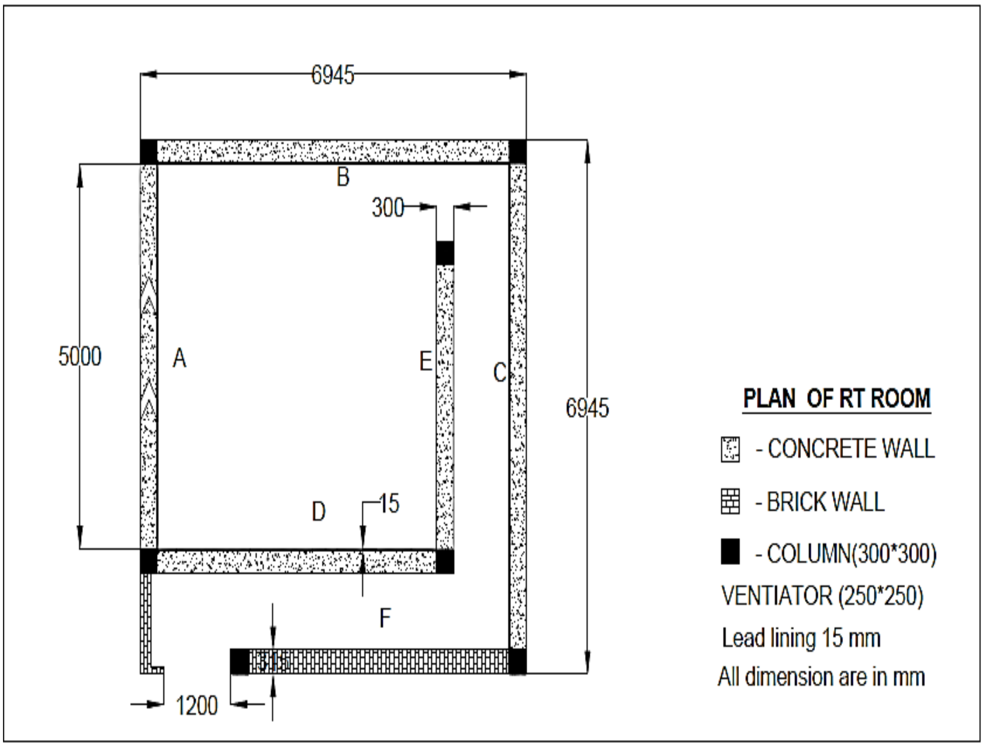

Fig.1. Plan of the radiographic testing room

VI. SAFETY MANAGEMENT

1. Safety objective is to protect individuals, society and environment from harm by establishing and maintaining effective defenses against radiological hazards from sources.
2. According to the Basic Safety Standards (BSS) we should ensure that during normal operation, maintenance and emergency situation, the radiation exposure is kept As Low As Reasonably Achievable (ALARA).
3. IS 18001:2007 gives detailed requirements of health and safety management systems.IS: 15793 gives requirements of good practices for managing environment, occupational health and safety legal compliance. They give guidelines for implementing them in construction project.
4. Emergency stop button and fire extinguishers should be made available at the working site.
5. Clearly visible signs bearing the radiation symbol and visible warning signals should be placed in suitable locations.
6. Personal monitoring devices and equipment like self-reading dosimeters should be used by the workers. The annual dosage should not exceed the limits given in the table below:

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TABLE 4
DOSAGE LIMIT OF RADIATION

Type of limit	Occupational dose per year	Public dose per year
Effective dose	20 mSv*	1 mSv
Lens of eye	150 mSv	15 mSv
Skin	500 mSv	50 mSv
Hands and feet	500 mSv	-

*mSv – milliSieverts

VII.EMERGFENCY PLAN

Emergency plans include the following:

- There should be an alarm to warn all inmates in case of emergency which should work even without power supply.
- There should be an emergency manager with an eminent team to handle the situation.
- There should be proper medical management with all the medical facilities conforming to the provisions of the Atomic Energy (Factories) Rules, 1996 should be provided at all work sites.
- A manned and equipped ambulance should be available at work site during the working hours/on round-the-clock shift basis.
- Display of emergency contact numbers of important persons and hospitals and route map of site shall be maintained at designated places.

VIII. CONCLUSION

Since the design of radiographic testing room involves greater concern towards safety the design has been made with sufficiency to protection against radiation hazards. It is concluded that normal concrete with 1:2:4 mixture is enough to provide radiation shielding and moreover the labyrinth design adds efficiency to the shielding. With proper planning and safety management we can achieve radiation hazards to the at most. Although lead is the most economic material in radiation shielding it is not environmental friendly. Hence further researches have to be made to replace lead with an eco-friendly material.

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