IUG Journal of Natural Studies
Peer-reviewed Journal of Islamic University-Gaza

ISSN 2409-4587

IUGNES
Special Issue, March, 2017, pp 351-358

Accepted on (14-03-2017)

Experimental study of the impact of adding recycled lead on the properties of concrete

Samir S. Yassin [1,*]
Mahmoud A. Alnajjar[2]

[1]Department of Physics, Faculty of Science Islamic University of Gaza, Gaza Strip, Palestine
[2]Department of Civil Engineering, Faculty of Engineering Islamic University of Gaza, Gaza Strip, Palestine

* Corresponding author
e-mail address: syassin@iugaza.edu.ps

In this work, recycle lead added in forms shots to constituent concrete in different percentage of lead-to-cement ratio (20% to 140%) by weight. Several tests on fresh and hardened concrete were carried out. The fresh concrete was tested and performed slump test to measure its workability. The testing on hardened concrete was compressive strength at 7 days, 14 days, and 28 days. The penetration of x-ray to concrete after 14 days from casting date was done by using basic x-ray machine as source at 100KeV and 120KeV energies and used X-Ray Dosimeter STEP OD-01 as detector to measure the radiation dose rate (μsv/h) penetrated the concrete samples. Then, linear attenuation coefficients (LAC) and compressive strength of concrete specimens were experimentally investigated. It was observed that, if the recycled lead shots to cement ratio of 80% by weight is added in the concrete mixture, the concrete can be used as a suitable shield against X- Rays.

Keywords:
: *Recycle lead; X-ray; lead shots; concrete;* radiation shields *compressive strength*.

1. Introduction:

Portland cement concrete is an ideal material for use in construction of radiation shields. Although there are other materials that could be employed for radiation shielding purposes, concrete is not only economical, but it also has the advantage of being a material that can be cast into any desired homogenous structural shape. Concrete is now commonly used for shielding of atomic research facilities, nuclear power plants, and for radiation medical and research units or equipment. Concrete is the most commonly used shield material as it is inexpensive and adaptable for any construction design (Singh et al., 2008), , it has acceptable strength and density for attenuation of gamma rays (Rezaei-Ochbelagh and Azimkhani , 2012). The presence of the large number of damaged car batteries in Gaza Strip which are harmful to the environment including land and human health problems according to the ministry of health (MOH). Therefore, it is necessary to dispose them by collecting them in a safe place and then recycling them. In recent years, many attempts have been made to increase radiation protection properties of concrete. Minerals such as magnetite, hematite, geothite and ilmenite were added as aggregates in concrete and their effects have been determined by Neville (Neville, 1996; Rezaei-Ochbelagh et al., 2010, 2011). Effects of barite and lead as additive materials in concrete have been separately investigated (Akkurt et al., 2010a,b; El-Hosiny and El-Faramawy, 2000). It is known that attenuation properties depend on the additives of concrete, thickness and density of specimen and gamma ray energy. Because of its toxicity, lead should be encased in concrete or be protected by heavy coats of paint or drywall (NCRP, 2005). In this research, the concrete containing lead shield was investigated for x-ray absorption. In order to verify the effect of lead, lead was used as shot in different size added to concrete.

1. Research Objectives

1. Disposal of harmful waste by using lead in concrete to reduce the environmental and health problems.
2. Determine concrete properties such as slump test, density and compressive strength at all recycled lead (RL) percentages.
3. Identify relation between admixtures added to concrete and the linear attenuation coefficients (index for shielding ability). Also, the half value layer (HVL) of the new type of concrete will be evaluated and determined.
4. Identify effect of change photon energy for linear attenuation coefficients (LAC) and half value layer (HVL).
5. Find optimum percentage of recycled lead (RL) to be used in improving X-

2. Methodology

☒ Preparation of concretes

- Waste lead sheets in car batteries was used as an additive after recycling it by a special method, added recycled lead in forms shots with maximum diameter of 1.18 mm to the constituents of concrete in different percentage of lead to cement ratio (20%, 40%, 60%, 80%, 100%, 120%, 140%) and mixing together to produce homogenous new concrete then casting it's in cubes and prisms.
- Obtained mixtures were molded into cubes with dimension of 100x100x100 mm for compression test and 200x200x (40, 60, 80, 100) mm prisms for x-ray penetration test.

☒ Testing of the samples:

A. Slump test on fresh concrete.
B. Compressive strength test on hardened concrete.
C. Penetration of x-ray to concrete samples.

3. Materials and set up of equipment

Concrete is a composite material made up of several different materials. The materials, which were used in the test program, included ordinary Portland cement, three types of aggregates, which had different gradations with three sizes see figure (1), clean sand, recycled lead shots and water.

The necessary tests are conducted in the laboratory of materials and soil in the Islamic University and in accordance with ASTM "American Society for Testing and Materials" and Radiology department in Al Shifa Medical Complex.

Figure 1 *Three types of natural coarse aggregate (Foliya, Adasiya and Simsimiya).*

4. Recycled Lead (RL):

Several steps performed to obtain recycled lead shots with maximum size of 1.18 mm added to concrete constituents in different percentages of lead-to-cement.

Steps of Obtaining Recycled Lead

Step 1: Collecting the damaged car batteries to get the lead sheets, see figure (2).
Step 2: Clean Lead sheets from impurities.
Step 3: Lead sheets are melt at a temperature more than 327 C that's lead melting temperature, see Figure (3).
Step 4: Dispose slag formed during the melting process.
Step 5: Pour lead liquid into molds after ensuring all slag was disposed, see Figure (4).
Step 6: Grind lead solid manually to shot form with maximum size of 1.18 mm.

(a) **(b)**

Figure 2 *(a) Damaged car batteries (b) Lead sheets.*

(a) **(b)**

Figure 3 *(a) Melting lead sheets at a temperature more than 327 C (b) Dispose slag.*

(a) **(b)**

Figure 4 *(a) Recycled solid lead (b) Recycled lead to shots with maximum size of 1.18mm*

Testing of recycled lead

Several tests and sieve analysis were carried out on recycled lead. The physical and chemical properties are shown in Table (1).

Casting procedures

The fresh concrete was cast in a timber moulds (200X 200X 40, 60, 80, 100 mm) to measure penetration x-rays radiation but steel cubes (100X 100X 100 mm) are used for compression strength test as shown in Figure (5).

(a) **(b)**

Figure 5 *(a) Form of timber moulds (b) Form of steel cubes*

Mix Proportion with Recycled Lead Shots (RLS) Material

Recycled lead shots (RLS) material was added to the normal concrete in different percentages. The percent and weight of recycled lead shots (RLS) material and the weights of the main constituents of concrete were listed in Table (2).

Table 1 *Physical and chemical properties of recycled Lead Shots.*

Property	Recycled Lead
Specific Gravity	11.2
Maximum Size (mm)	1.18
Color	Lead- Gray
Lead Percentage (%)	83.60

Table 2 *Mix design of the concrete cube samples.*

	Weight per one cubic meter kg/m3							
Materials	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8
Coarse aggregate(Foliya)	245	245	244	243	242	241	239	238
Coarse aggregate(Adasiya)	350	349	348	346	345	344	342	340
Coarse aggregate(Simsimiya)	561	559	557	554	552	550	547	544
Fine aggregate "sand"	640	638	635	633	630	627	624	621
Cement	350	349	348	346	345	344	342	340
Recycled lead "RL"	0	70	139	207	275	342	410	476
Water	220	219	218	217	216	216	214	213
Expected density	2367	2429	2488	2548	2606	2665	2720	2774

Casting procedures

The fresh concrete was cast in a timber moulds (200X 200X 40, 60, 80, 100 mm) to measure penetration x-rays radiation but steel cubes (100X 100X 100 mm) are used for compression strength test as shown in Figure (5).

(a) (b)

Figure 5 *(a) Form of timber moulds (b) Form of steel cubes*

After 20-40 hours, the hardened concrete is removed carefully from the molds to prevent any defects in the samples.

After that, the compression test samples are placed in curing water tank at temperature 21-25°C until the period of testing but the penetration test samples are cured by spraying water five times daily for a week, see Figure (6).

(b) (a)

Figure 6 *Curing process for (a) Samples of penetration test (b) Samples of compression strength test*

Equipment and Testing Procedure

Concrete were test and performed as follows, the first is slump test on fresh concrete . The second test relates to compressive strength of concrete specimens were experimentally investigated after 7days, 14daye, and 28days on (10x10x10cm) cubes see figure (7), and the third test is the penetration of x ray to concrete after 14 days from cast at 100KeV and 120KeV energies, used X-Ray-Dosimeter STEP OD-01 to achieve that and measured absorbed dose to concrete sample at different thickness(4,6,8,10cm) and different recycle lead percentage (20-140%).

(a) **(b)**

Figure 7 *(a)Slump value determination (b) Compressive strength testing machine*

X-Ray Penetration Test:

All samples were tested in radiology department in Al Shifa Medical Complex at room no. 6, using basic x-ray machine as source and borrowed X-Ray Dosimeter STEP OD-01 as detector from Al Ameer Nayaf Center to measure the radiation dose rate (μsv/h) penetrated the concrete samples see figure(8).

(a) **(b)**

Figure 8 *(a)The radiation parameters of x-ray machine (b) Radiation survey meter*

Procedures to perform penetration test:

- After 14 days the samples were taken to the radiology department in Al Shifa Medical Complex (room no. 6) and exposed to radiation of basic x-ray machine.
- Using for this test samples with different thickness 200 X 200 X (40, 60, 80 and 100) mm for each batch.
- Recycled lead shots RLS to cement ratio change for each batch, ratios used are (20%, 40%, 60%, 80%, 100%, 120%, 140%)
- The test was performed at different energy 100 KeV and 120 KeV to study the energy effect for shielding parameters.

- Source object detector distance (SOD) is 70 cm is distance from source x-ray radiation to concrete sample, source dosimeter detector distance (SDD) is 81 cm is distance from source x-ray radiation to detector, see figure(9).

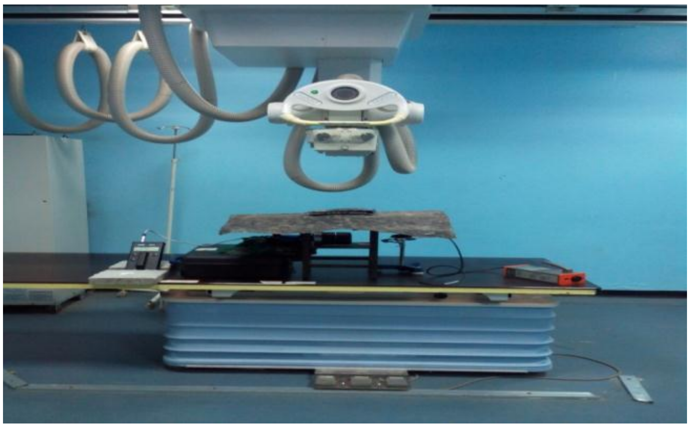

Figure 9 *Penetration test operation***.**

☒ Results and Discussion

The performed experimental program is carried out to obtain and evaluate the mechanical and shielding x-ray properties of fresh and hardened concrete under several percentages of recycled lead shots to cement ratios.

Slump Test

The slump value was used as an indication of mix workability, figure (10) shows a decrease in workability when the percentage of recycled lead shots increases. This decrease ranged from 110 mm for normal concrete without RLS to 45 mm for 140% of RLS.

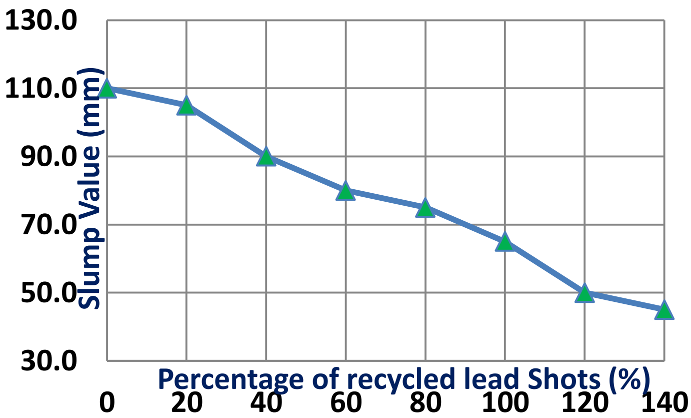

Figure 10 *Relation between the ratio of RLS and slump value.*

Workability of concrete decreases may be attributed to the cohesion properties of RLS decreases workability between of the concrete mix. And shape of RLS is irregular which causes interact force between the constituents of concrete.

Density

Density of normal concrete without RLS was 2361.3 Kg/m^3, after adding 140% of RLS the density of concrete increased to 2762.0 Kg/m^3. This means that adding 140% of RLS increases concrete density to about 17.0% see figure (11).

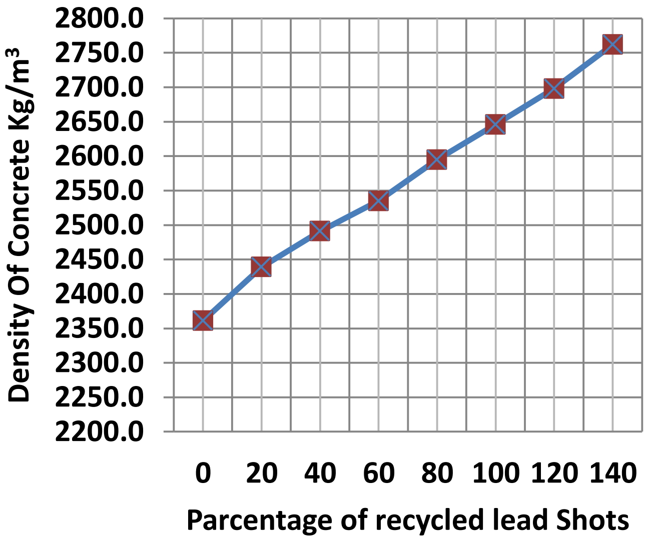

Figure 11 *Average 28 day concrete density versus percentage of RLS***.**

The density of concrete increases due to fine RLS graduate has filled up tiny voids in concrete specimen and Lead shots have high density 11.2 g/cm^3 compared to densities of constituents of concrete.

Compressive Strength

From the result of compressive strength for normal concrete and concrete with RLS at 7, 14 and 28 day, which listed in Table (3) and Figure (12), noted that the compressive strength at 28 days increased from 37.06 MPa at 0% of RLS to 47.57 MPa at 80% of RLS. After that, when the RLS to cement ratio was increased from 80% to 140% concrete compressive strength decreased from 47.57 MPa at 80% of RLS to 35.33 MPa at 140% of RLS.

Table 3 *Compressive strength at 7,14 and 28 days of age and percent of* f_{cut}/f_{cu28} *for normal concrete and with RLS concrete.*

Concrete Type	Compressive strength at age (MPa)			f_{cut}/f_{cu28} (%)		
	7 days	14 days	28 days	7 days	14 days	28 days
Normal concrete	25.3	33.1	37.1	68.2	89.2	100
Concrete with 20%RLS	32.3	38.0	44.6	72.4	85.2	100
Concrete with 40%RLS	33.9	40.0	45.1	75.2	88.7	100
Concrete with 60%RLS	35.1	43.3	46.5	75.5	93.1	100
Concrete with 80%RLS	35.7	41.4	47.6	75.0	87.0	100
Concrete with100%RLS	33.5	39.7	45.4	73.8	87.4	100
Concrete with120%RLS	30.1	32.4	37.6	80.1	86.2	100
Concrete with140%RLS	28.8	32.4	35.3	81.6	91.8	100

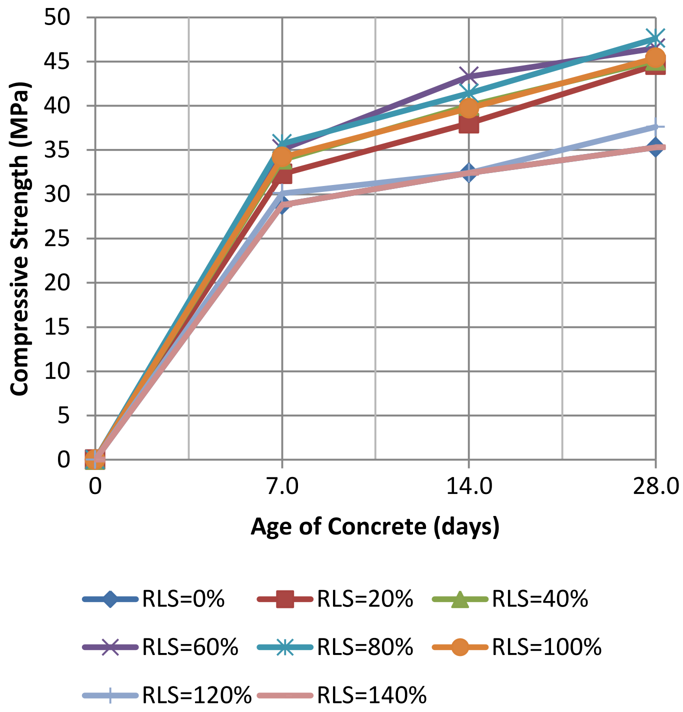

Figure (12) *Age and compressive strength relationship for normal concrete and with RLS.*

Compressive strength of concrete is improved by adding lead shots with maximum size of 1.18 mm due to the density of concrete is improved because the lead shots have filled up pores in concrete and sieve analysis of the mix design was improved and the lead causes the formation of Pb(OH)2 and enhanced the formation of a larger amounts of calcium silicate hydrates (C–S–H) and calcium aluminate hydrates (C–A–H) (El-Hosiny and El- Faramawy, 2000). That is an important bound on concrete hydration.

Compressive strength of concrete decreases by adding lead shots with maximum size of 1.18 mm due to filling pores in concrete and extra lead shots play negative role in decreasing cohesion between concrete constituents.

Penetration X-Ray Test Results

The penetration of x-ray radiation to concrete after 14 days from casting date at100KeV and 120KeV at different concrete sample thicknesses (4, 6, 8, 10 cm) and different recycled lead percentages (0% to 140%) is evaluated.

The results show that LAC of concrete increased by increasing the lead shot percentage for both x-ray energy at 100 Kev and 120 Kev. It is found that LAC in the absence of lead is 0.31 cm^{-1}, whereas the ratio of RLS 140%, the LAC is 0.48 cm^{-1} at100 Kev.

Half value layer(HVL) thickness is the other parameter that evaluated or x-ray shielding. This variation of HVL against an increasing lead percentage in concrete at 100Kev is reduced by increasing from 2.24 cm for normal concrete without RLS to 1.41 cm for 140% of RLS. Table (3) shows shielding parameters for concrete at two energies;100 KeV and 120 KeV.

Conclusions & Recommendations

The result of this research showed that adding recycled lead in shots form with maximum size 1.18 mm can enhance the mechanical property of hardened concrete

as compressive strength and shielding properties, with different percent of enhancing.
It is observed from this study that when the lead-to-cement ratio is increased from 0% to 80%, its compressive strength and x-ray shielding properties are improved with maximum values obtained at 80%. However, when the lead-to-cement ratio is increased

Table 3. *Average LAC, MAC, HVL, TVL and RLS ratio at energy 100 KeV and 120 KeV*

RLS (%)	Density (Kg/m^3)	At Energy 100 KeV				At Energy 120 KeV			
		LAC $\mu(cm^{-1})$	MAC $\mu_m(cm^2/g)$	HVL (cm)	TVL (cm)	LAC $\mu(cm^{-1})$	MAC $\mu_m(cm^2/g)$	HVL (cm)	TVL (cm)
0%	2361.3	0.310	0.131	2.24	7.43	0.130	0.055	5.33	17.72
20%	2438.8	0.340	0.139	2.04	6.77	0.139	0.057	4.99	16.57
40%	2490.8	0.380	0.153	1.82	6.06	0.157	0.063	4.41	14.67
60%	2520.7	0.400	0.159	1.73	5.76	0.169	0.067	4.10	13.63
80%	2564.8	0.420	0.164	1.65	5.48	0.229	0.089	3.03	10.06
100%	2615.3	0.440	0.168	1.58	5.23	0.241	0.092	2.88	9.556
120%	2648.4	0.460	0.174	1.51	5.01	0.300	0.113	2.31	7.677
140%	2708.0	0.490	0.181	1.41	4.70	0.325	0.120	2.13	7.086

from 80% to140%, the x-ray shielding properties of concrete is increased but the compressive strength is decreased. This indicates that higher values of RLS percentage in concrete is unsuitable for shielding, where compressive strength is reduced.
The results have demonstrated that the density of concrete increases as the percentage of recycled lead shot increases, and the workability of concrete decreases when recycled lead shot ratio increases.
The optimum percentage of RLS to be used is 80% had a significantly higher compressive strength (47.57 MPa compared to 37.06 MPa for normal concrete) and the slump value was 75mm with true shape and without segregation.

Recommendations for Further Studies

1. It's recommended to use recycled lead shots in concrete slabs because of its good contribution to improve x-ray radiation resistance of concrete and the compression strength of new concrete was improved.
2. Natural aggregate can be replaced by denser aggregate with larger specific gravity to improve shielding properties of concrete such as basalts.
3. Organic material such as polymers may be added to concrete. The strength and penetration x-ray radiation characteristics identified for anew concrete.
4. Adding recycled lead shots should be done on other concretes form such as concrete slabs, blocks by different size and plaster and study its influence on strength and shielding properties.
5. Using recycled lead in concrete mixes leads to conserve high cost waste to buy new plate and construct thick concrete wall and to reduce the amount of danger waste that must be disposed of in landfills.
6. Performing recycled lead operation under technical supervision to avoid any negative effect on worker and people health needs to identify special place to collect rubbish batteries and recycled operation.
7. Investigated new concrete for durability use several tests such as fire resistance, chemical attack, freezing and thawing

References

Akkurt, I., Akhyildirim, H., Mavi, B., Kilincarslan, S., & Basyigit, C. (2010). Gamma-ray shielding properties of concrete including barite at different energies. Prog. Nucl. Energy 52, 620-623.
Akkurt, I., Akhyildirim, H., Mavi, B., Kilincarslan, S., & Basyigit, C. (2010). Photon attenuation coefficients of concrete includes barite in different rate. Ann. Nucl. Energy 37,910-914.
El-Hosiny, F., & El-Faramawy, N. (2000). Shielding of gamma radiation by hydrated Portland cement–lead pastes. Radiat. Meas. 32, 93-99.

Neville, A. (1996). 4th edition Properties of Concrete. John Wiley and Sons, Inc., New York, pp. 844.

NCRP Report No. 151. (n.d.). Struct`ural shielding design and evaluation for megavoltage X- and gamma-ray radio- therapy facilities. Bethesda, MD, USA: NCRP Report No. 151.

Rezaei-Ochbelagh, D., Gasemzadeh Mosavinejad, H., Molaei, M., Azimkhani, S., & Khodadoost, M. (2010). Effect of low dose gamma radiation on concrete during solidification. IJPS 5 (10), 1496-1500.

Singh, K., Singh, N., Kaundal, R., & Singh, K. (2008). Nuclear Instruments and Methods in Physics Research. B, 266, p. 944.

في هذا العمل تم اضافة الرصاص العادم المسحوق على شكل شظايا صغيرة جدا الى الخرسانة وذلك بنسب مختلفة من الرصاص الى الأسمنت (20% الى 140%) بالوزن و أجريت عدة اختبارات على الخرسانة الطازجة الصلبة، حيث تم اختبار الركود لقياس قابليتها للتشغيل. و كان الاختبار على صلابة الخرسانة و مقاومة الضغط في 7 أيام، 14 يوما، و 28 يوم ثم استخدم جهاز الأشعة السينية كمصدر للأشعة بطاقة KeV100 و KeV120 لقياس قدرة اختراق الأشعة للخرسانة. تم استخدام STEP OD-01 ككاشف لقياس معدل جرعة الاشعاع (µsv / ساعة) واختراق عينات الخرسانة ثم تم الحصول علة معاملات التوهين الخطي و مقاومة الضغط للعينات الخرسانية

كلمات مفتاحية:
الرصاص العادم،
الأشعة السينية،
الخرسانة،
الوقاية الاشعاعية،
مقاومة الخرسانة.