Journal of Civil & Environmental Engineering

Rabie, J Civil Environ Eng 2016, 6:1
DOI: 10.4172/2165-784X.1000209

Research Article Open Access

Using of Wastewater Dry and Wet Sludge In Concrete Mix

Ghada Mourtada Rabie*

Sanitary and Environmental Department, Cairo University, Egypt

Abstract

The aim of this thesis is to implement a new way of discarding the large amount of sludge which produced from the wastewater treatment plants in Egypt, since the amount of sludge produced every year in Egypt are about "4 Million ton ", this amount of sludge is considered a big/dangerous problem which facing Egypt today. Thus, all over the world the researchers are trying to explore a new and suitable way to solve the sludge huge amount which produced from the WWTPs. One track of these solutions is to use sewage sludge in Construction field" concrete mixtures and in manufacturing interlock brick samples'', evaluated the reuse of sewage sludge from urban wastewater treatment plants in a mixture with cement and to develop new construction materials. According to results findings, no significant strength loss was observed when using the dry or wet sludge with different percentages from the cement weight, in which the strength loss was increased to 63.7% after 7-days and 61.6% after 28-day for dry and for wet 73.4% after 7-days and 68.5% after 28-days when 20% of wet and dry sludge pellets by cement weight was added to concrete mixture. The results showed that the wet sludge retarded the strength development and has more adverse effect on compressive strength than the other dry sludge for the same percentage as the average strength loss after 28-days for wet percentages approximate about 13.76% and for dry sludge approximate about 7.73%. Finally the study concluded that the dry and wet sludge can be used in as an additive to concrete mixtures till 15% form cement weight as one of the available disposal options for Egypt sludge. The study recommended that more researches are needed to evaluate the durability of sludge concrete and the behavior of reinforced sludge concrete.

Keywords: Concrete mix; Compressive strength; Egypt; Sewage Sludge; Sludge management

Introduction

The treatment and disposal of sewage sludge is an expensive and environmentally sensitive problem. It is also a huge problem which facing the world-wide from many years, since sludge production will continue to increase as new sewage treatment works are built and environmental quality standards become more difficult [1]. With some traditional disposal ways coming under pressure, and others like land disposal having been phased out the challenge facing countries is to find cost effective and creative ways while responding to environmental, regulatory and public pressures. Recycling and use of wastes are the desirable options for sustainable development, rather than incineration, land spreading and land filling [2-5]. The Egyptian population has tripled during the last 50 years and still grows each year by approximately 1.5 million people, the total population increased from 22 million in 1950 to 80, millions in 2008, and is likely to increase to above 96 million by 2026. With the rapidly growing population and industrial development, wastewater generation has been increased and is also expected to increase significantly in the future. The Egyptian sanitation sector is facing many difficulties to manage this wastewater mainly due to financial problems, which require huge investments far above the presently available national resources. The Government of Egypt has invested more than 24 billion US$ in development of water and wastewater services over the last 20 years and plans to invest about 20 billion US$ in the next 10 years [6-9]. In recent years, sewage sludge has become an international topic with numerous conferences and this activity reflects the growing realization that while world sludge production is on a relentless growth curve, environmental quality requirements for sludge are becoming increasingly stringent, disposal outlets are decreasing and yet economic pressures still require low-cost solutions to sludge disposal problems. Due to the strict environmental laws and the flagrant environmental side effects which caused due to the traditional sludge disposal ways, the Government's urgently try to find new ways to get rid form the large quantities of waste water sludge without harm the humankind or harm the environment, one of this new methods is Using the dry sludge in the construction materials like (concrete mix for non-reinforced concrete, in making the bricks, and Glass too). For many years, the methods and technologies for sewage sludge treatment, which are implemented in Egypt, are very limited the main attention was concentrating on the process of sludge drying, mainly through natural drying beds without any concern about the characteristics or quality of the produced sludge. Recently, there is an interest in expanding the use of new techniques and ways for sewage sludge treatment. Most of Egypt cities have treated the municipal sewage by partially technological treatment methods since 1980's, but today, many small towns and municipalities in Egypt already have or plan their own sewage treatment plants. One thing often not considered is the amount of sewage sludge produced and to be disposed of or reused. There is an annual amount of 12 – 15 kg of solid matter in the sewage sludge per inhabitant in Egypt, which corresponds to a daily production of 35 – 40 g. The share of solid matter (organic and inorganic material produced within the sewage treatment process) depends on the pollution of the raw sewage and on the respective sewage treatment and sludge drainage system and is usually between 1% and 3%. Higher amounts of solid matter (4–10%) may be achieved by thickeners, which pre-drain the sludge mechanically and partially stabilize it. These large quantities of sludge which generated each year from the water treatment plants in Egypt are disposed into the Nile River, the cities which located far from the Nile River banks dispose the sludge in the nearest empty land beside the WWTPs. This sludge contains at least 96% water [10], which causes certain environmental problems and health hazards in the future. There's a world trend concerning sludge management are talking about converting the produced Sludge into useful materials not harmful to the human begin.

***Corresponding author:** Ghada Mourtada Rabie, Sanitary and Environmental Department, Cairo University, Egypt, Tel: +20 2 35676105; E-mail: ghada.mourtada@yahoo.com

Received December 03, 2015; **Accepted** January 21, 2016; **Published** January 23, 2016

Citation: Rabie GM (2016) Using of Wastewater Dry and Wet Sludge In Concrete Mix. J Civil Environ Eng 6: 209. doi:10.4172/2165-784X.1000209

Sludge treatments facilities are almost not exist. The treatment process is ended by disposing the partially treated wastewater to the Sea or by flooding agriculture land And dispose dewater sludge in the sand areas around plants without any treatment. These disposal methods are forbidden in most European countries and United States due to the dangerous effects to human health and pollution of marine and costal. Consequently, these problems concerning the environmental impact of the traditional sludge disposal ways which used in the developing countries can be mitigated by searching for a new and easy disposal options with low cost other than disposal the sludge on land or disposal it into the sea or using it as a fertilizer for agriculture. Thus, many researchers worldwide spotlight on reusing sludge, and treated wastewater in construction technology. Finally, This work was directed toward scrutinize the feasibility of using the dry and wet sludge resulting from (WWTPs) with different percentages for non-reinforcement concrete mix and how it will affect the main characteristics of the concrete mix like (Compressive Strength, Workability…), compared with the different percentages of the dry and wet sludge. The successful use of sludge will help in reducing the Environmental and health problems related to the bad handling of sewage sludge at wastewater treatment plants and the scarcity of land area needed for disposal.

Materials and Methods

Materials

Sludge: The sludge was brought from EL-BADRASHEN wastewater plant. This plant was chosen due to better management and operation system than other plants which suffer from overloading and poorly management. Sludge samples were obtained from drying beds site. The sludge in this plant is exposed to sun for long period in the drying beds. The produced sludge has varying moisture depending on weather, temperature and sludge depth.

Dry sludge: The sludge was brought from EL-BADRASHEN wastewater plant and after that the sludge is dried on oven with temperature 200°C for about one-half hours. Then the sludge grinding and sifts out in sieve (4.75 and 2.36 mm) size (Figure 1).

Wet sludge: The sludge was brought from EL-BADRASHEN wastewater plant and after that the sludge is grinding and sifts out in sieve (4.75 and 2.36 mm) size (Figure 2).

Cement: Portland cement type -R with Grade 42.5 was used throughout the investigation. The cement was obtained from local concrete manufacture and kept in dry location.

Water: Tap water, potable without any salts or chemical was used in the study.

Aggregate: In general, aggregates make up 60%-75% of the total concrete volume, so their selection is important, because they control concrete properties. Two main categories of aggregate were used coarse (with dry unit weight 1650 kg/m^3) and fine aggregates (with dry unit weight 1800 kg/m^3). The coarse aggregate in this work was crushed limestone. Three size of coarse aggregate were used with maximum size greater than (5 mm). The appearance of these aggregate are shown in Figure 1. The aggregate are classified into fine and coarse. The sieve analysis of aggregate includes the determination of coarse and fine aggregate by using a series of sieves (Figure 3).

Methods

Concrete mix design: Concrete without sewage sludge was used as the control concrete, in which it prepared to investigate the influence of dry and wet sludge on concrete main properties. Mix was designed with a targeted compressive strength 250-300 kg/cm^2. No mineral or chemical admixtures were added to mix. The mix operation of concrete control mixes and concrete with sludge mixes were taken place in a conventional blade-type mixer. Table 1 summarized the mix operation procedure which followed for all control and sludge concrete mixes

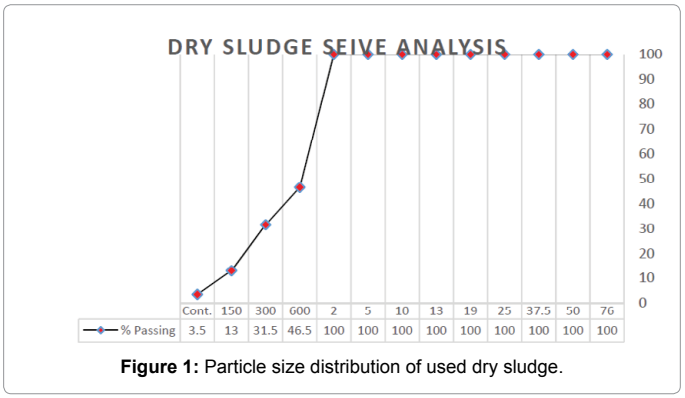


Figure 1: Particle size distribution of used dry sludge.

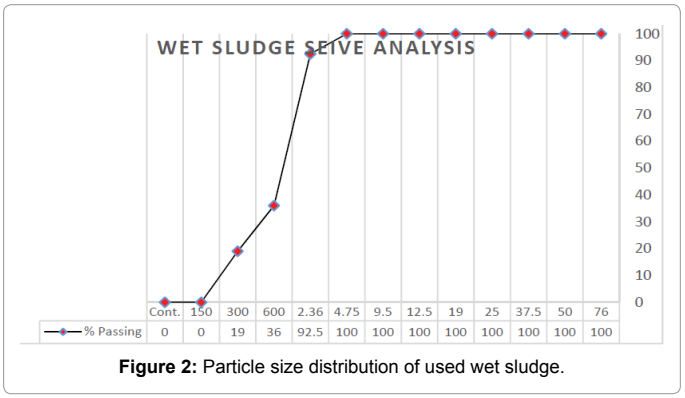


Figure 2: Particle size distribution of used wet sludge.

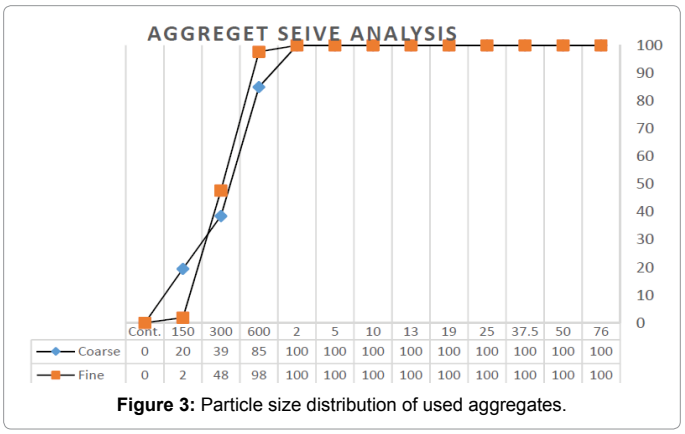


Figure 3: Particle size distribution of used aggregates.

Step Number	Description
1	Prior to start mix, add coarse aggregate, some of mixing water which may contain admixture if required
2	Start mixer
3	Add fine aggregate contained sludge, cement, and remaining water with mixer running
4	With all ingredients in the mixer, mix for 3 minutes
5	Stop mixing for 3 minutes
6	Mix for 2 minutes

Table 1: Mixing procedure according to ASTM.

without any change. The sludge amount was mixed with sand to achieve homogeneous mixture. The process of determining required and specifiable characteristics of a concrete mixture is called mix design. Mixture proportioning refers to the process of determining the quantities of concrete ingredients, using local materials, to achieve the specified characteristics of the concrete. The design of concrete mixtures in this work involves the selection of proportions of available materials to produce concrete of required properties, with the greatest economy.

1. The required concrete strength is fcylinder=300 kg/cm^2 at 28 day.

2. Water cement ratio (w/c) is determined. For non-entrained concrete and compressive strength 300 kg/cm^2≈30 Mpa, water to cement ratio (w/c)=0.5 (Figure 2 and Table 2).

3. Concrete mix consist of cement, coarse aggregate, and fine aggregate According to the weight Percentages: Cement: 1 fine aggregate: 2 coarse aggregate: 4 in which W/C=0.5

Testing program

The testing program comprises obtaining fresh properties by applying the slump test and the compressive Strength of all samples at 7, 28 days. The 15*15*15 cm mould cubes were used to obtain the samples for Compression testing and at least 3-cubes were considered for each test result. When utilizing dry and wet sludge as an additive, concrete mix having 0,5,10,15 and 20% of cement weight, the effect of the dry and wet sludge on concrete properties was examined like (workability, compressive strength and densities) was studied.

The following tasks will be adopted to achieve the research objective:

1. Site visit to the El-BADRASHEN WWTP to get the sludge sample from drying beds.

2. Collecting the relevant information and data from (El-BADRASHEN WWTP) related to sludge

treatment process, their quality, quantity, percentage of main components.

3. Dry the sludge from El-BADRASHEN WWTP stage in the oven at 200°C about 2-hours.

4. Mixed with different ratios (0, 5, 10 and 20%) of cement weight.

5. Making Sieving analysis for dry and wet sludge after grinding the sludge.

6. Doing BOD test for Wet and Dry sludge.

7. Doing TSS test for Wet and Dry sludge.

8. Making specimen cubes (15*15*15 cm) for each mix to do concrete strength test after (7-28) days.

9. Doing the Slump Test for test workability of concrete mix.

10. Calculate density for each concrete mix with the different Percentages (0, 5,10 and 20%).

Mix	Cement	Course aggregate	Fine Aggregate
High compressive strength	1	2	1
Medium compressive strength	1	4	2
Low compressive strength	1	5	3

Table 2: Mix different Types.

Analysis the experimental tests results and draw conclusions (Charts) that present the following:

1. The effect of sludge type (Wet and Dry) produced from drying beds at El-BADRASHEN WWTP on the concrete strength after 7-days.

2. The effect of sludge type (Wet and Dry) produced from drying beds at El-BADRASHEN WWTP on the concrete strength after 28-days.

3. The effect of sludge type (Wet and Dry) produced from drying beds at El-BADRASHEN WWTP on the concrete workability (Slump Test).

4. Sieve analysis results for wet and dry sludge after grinding and for fine and coarse aggregate.

5. The optimum dry and wet sludge percentage to cement ratio which can be used in concrete mix without great effect on concrete strength or workability.

6. Variance% after 7-days and 28-days for wet and dry sludge's with the different percentages (0, 5, 10, and 20%).

Results and Discussion

Type I dry sludge

Type I dry sludge was added to concrete mix with different percentages (5, 10, 15 and 20%) of total cement content. The influence of these sludge percentages on the slump value, concrete density and compressive strength.

Slump value

When dry sludge content in concrete is 5% or less, slight change in slump test observed when applying dry sludge as an replacement material from concrete weight, However for the mixes more than 5% decreased the workability of the mix around 2.7 cm difference than control mix and subsequently caused a reduction in the slump value obtain are explained in Table 3. These findings are contradicted with the results obtained by Valls et al. in which the slump test increases with increasing the% of sludge in concert mix, although these findings are generally agreed with the results obtained by Jamshidi et al. [11] also Mattar et al. [12], as using higher sludge percentages more than 5% decrease the workability of the mix and subsequently causes a reduction in slump.

Density

The density of the tested concrete mixes slightly to moderately decreased as sludge content increased, which agrees that the reduction in density of sludge was higher when dry sludge was used than counterpart percentages for wet sludge are explained in Table 4. These findings are agreed with the results obtained by M. Mattar et al. [12], the density of the concrete decreased in all cases with increasing sludge content.

Compressive strength

The results of compression testing of cubes showed that the compressive strength reduces as the sludge content increases. Dry sludge less than 15% can be used as an additive to concrete mix without causing a marked reduction in compressive strength. 5% dry sludge by cement weight can be added to concrete mix with introducing slightly change around 1.3% after 28-days in mix preparation difference. The results showed that 20% of cement weight for dry sludge led to a

significant decline in compressive are explained in Table 4 and Figure 3 [13].

Compressive strength Summery results for mix with dry sludge

These findings contradict in general with those obtained by Jamshidi, Jamshidi and Mehrdadi et al. [11] as concrete containing 20% dry sludge showed acceptable results in which, by increasing the dry sludge content in concrete by 20% in concrete sample a decrease about 20% showed in compressive strength [14-16].

Influencing of dry sludge in drying period

For dry sludge different percentages, the required drying period after pouring it in the mould increased with increasing the dry sludge percentages, Moreover for 20% dry sludge from cement weight it take about 2-weeks to be dried in order to remove it from the mould and prepare it for curing (Tables 3 and 4, Figure 3).

Type II wet sludge

Type I wet sludge was added to concrete mix with different percentages (5,10,15 and 20%) of total cement content. The influence of these sludge percentages on the slump value, concrete density and compressive strength [17-19].

Slump value

When wet sludge content in concrete is 5% or less, slight change in slump test observed when applying wet sludge as an replacement material from concrete weight, However for the mixes more than 5% decreased the workability of the mix around 2.25 cm difference than control mix and subsequently caused a reduction in the slump value obtain are explained in Table 5.

Density

The density of the tested concrete mixes slightly to moderately decreased as sludge content increased, which agrees that the reduction in density of sludge was lower when wet sludge was used than counterpart percentages for dry sludge are explained in Table 3.

Compressive strength

The results of compression testing of cubes showed that the compressive strength reduces as the sludge content increases. Wet sludge less than 15% can be used as an additive to concrete mix without causing a marked reduction in compressive strength. 5% wet sludge by cement weight can be added to concrete mix with introducing moderate change around 5.7% after 28-days in mix preparation difference [20-23]. The results showed that 20% of cement weight for wet sludge led to a significant decline in compressive are explained in Table 6 and Figure 4.

Concrete Mix	Slump Test (cm)
5% dry sludge	7
10% dry sludge	6
15% dry sludge	5
20% dry sludge	3.5

Table 3: Slump test analysis results for Type I.

Influencing of dry sludge in drying period

For dry sludge different percentages, the required drying period after pouring it in the mould increased with increasing the dry sludge percentages, Moreover for 20% dry sludge from cement weight it take about 2-weeks to be dried in order to remove it from the mould and prepare it for curing (Tables 5 and 6, Figure 4). In general, the rate of strength and density developed for all sludge concrete were lower compared to control mix without sludge. The results indicated that due the reduced workability of concrete mix with sludge content more than 10% could adversely affected the preparation of concrete (Figure 5). These findings agree in general with those obtained by Mattar et al. [12], who showed that the presence of sludge reduces mechanical strengths of the concrete and this reductions increases as the sludge content increases [24-26]. Although this study showed a lower reduction in compressive strength. It indicates that the 10% sludge concrete mixes showed the worst results, which agree with Valls, However in this study the 20% of concrete mix for the wet and dry sludge showed the worst results (Figures 5-7).

Conclusion

The aim of the current study is to obtain the influence of dry and wet municipal waste water sludge on the physical mechanical properties of concrete mixes. In which the investigation properties involved workability, density, compressive strength. Accordingly based on the experimental investigation reported in the work, the usage of sewage sludge in concrete mixes as an alternative solution for disposal for Egypt WWTPs, the conclusions, which can be drawn, based on the experimental results are:

1. The results show that the dry sludge different percentages (5,10,15 and 20%) are higher than the Counterpart percentages for the wet sludge.

2. Dry sludge less than 15% can be used as an additive to concrete mix without causing a marked reduction in compressive strength. 5% dry sludge by cement weight can be added to concrete mix with introducing slightly change around 1.3% after 28-days in mix preparation difference.

3. However, increasing the percentages of added dry sludge more than 5% decreased the workability of the mix around 2.7 cm difference than control mix and subsequently caused a reduction in the slump value obtained.

4. The results showed that 20% of cement weight for dry sludge led to a significant decline in compressive strength about 61.6% of control strength after 28-day age curing.

Mix Type	After 7-days			After 28-days		
	Failure Load (Ton)	Stress (Kg/cm^2)	Average Density (Kg/m^3)	Failure Load (Ton)	Stress (Kg/cm^2)	Average Density (Kg/m^3)
5% dry sludge	56.3	256	2347	58.4	260.0	2294
10% dry sludge	52.3	239	2260	53.8	241.7	2254
15% dry sludge	45.14	201	2252	50.5	226.7	2237
20% dry sludge	21.23	94	2131	22.6	101.0	2231

Table 4: Compressive strength and density analysis results.

Concrete Mix	Slump Test (cm)
5% wet sludge	7
10% wet sludge	5.5
15% wet sludge	4.5
20% wet sludge	4

Table 5: Slump test analysis for wet sludge results.

Mix Type	After 7-days			After 28-days		
	Failure Load (Ton)	Stress(Kg/cm^2)	Average Density (Kg/m^3)	Failure Load (Ton)	Stress (Kg/cm^2)	Average Density (Kg/m^3)
5% wet sludge	54	242	2358	56.3	248.3	2334
10% wet sludge	46	225	2295	52.093	230.7	2259
15% wet sludge	44	196.7	2272	45.22	202.3	2242
20% wet sludge	15.2	69	2149	18.453	83	2236

Table 6: Compressive strength analysis for wet sludge results.

5. For dry sludge different percentages, the required drying period after pouring it in the mould increased with increasing the dry sludge percentages, Moreover for 20% dry sludge from cement weight it take about 2-weeks to be dried in order to remove it from the mould and prepare it for curing.

6. The adverse effect of dry sludge on concrete compressive strength increased as the slump value decreased. The compressive strength of concrete mix contained 5% sludge decreased by 1.3% after 28-days when the mix slump was 7 cm and 20% sludge decreased by 61.6% after 28-days when the mix slump was 3.5 cm.

7. Wet sludge less than 15% can be used as an additive to concrete mix without causing a marked reduction in compressive strength. 5% wet sludge by cement weight can be added to concrete mix with introducing slightly change around 5.7% after 28-days in mix preparation difference.

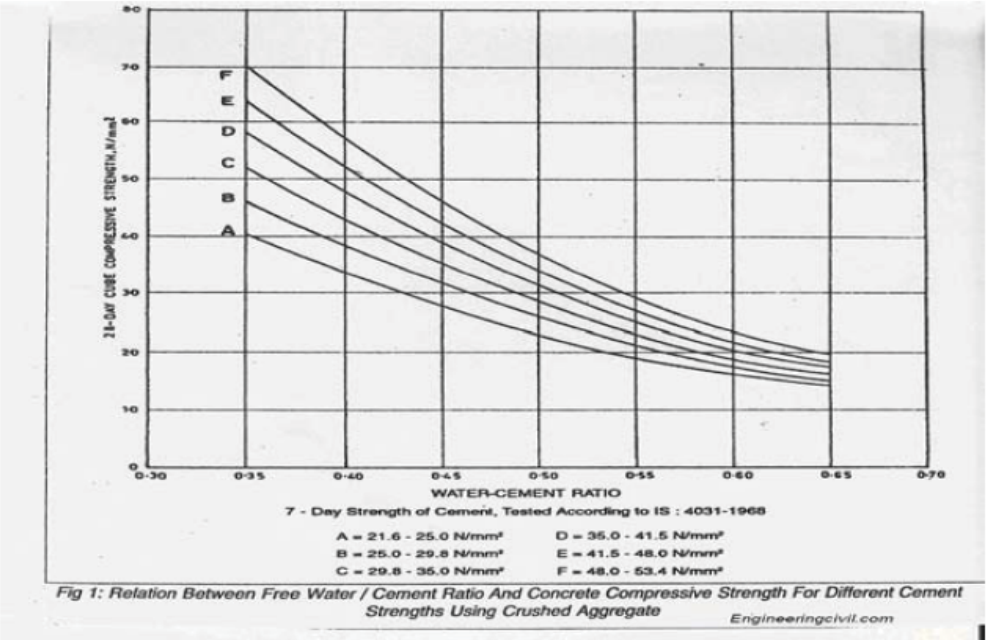


Figure 4: Approximate relationship between compressive strength and w/c ratio for concrete.

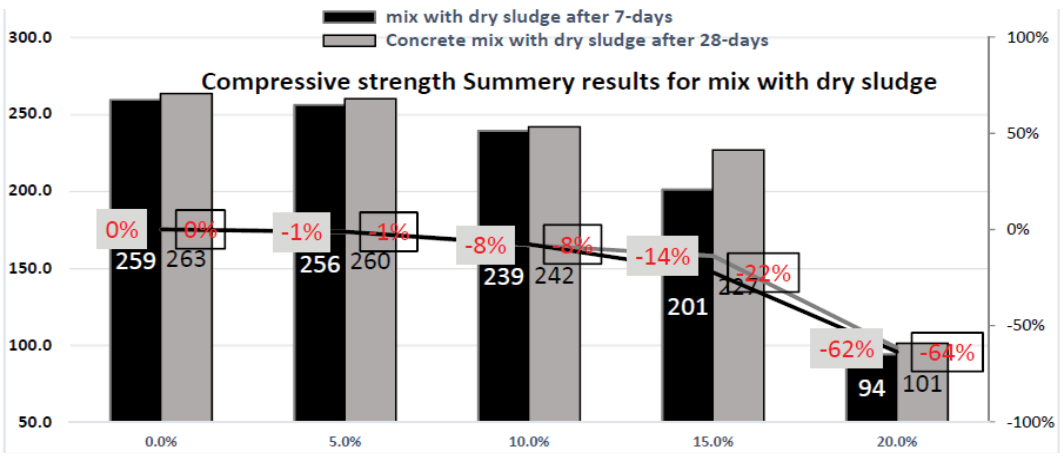


Figure 5: Slump test analysis results for Type I.

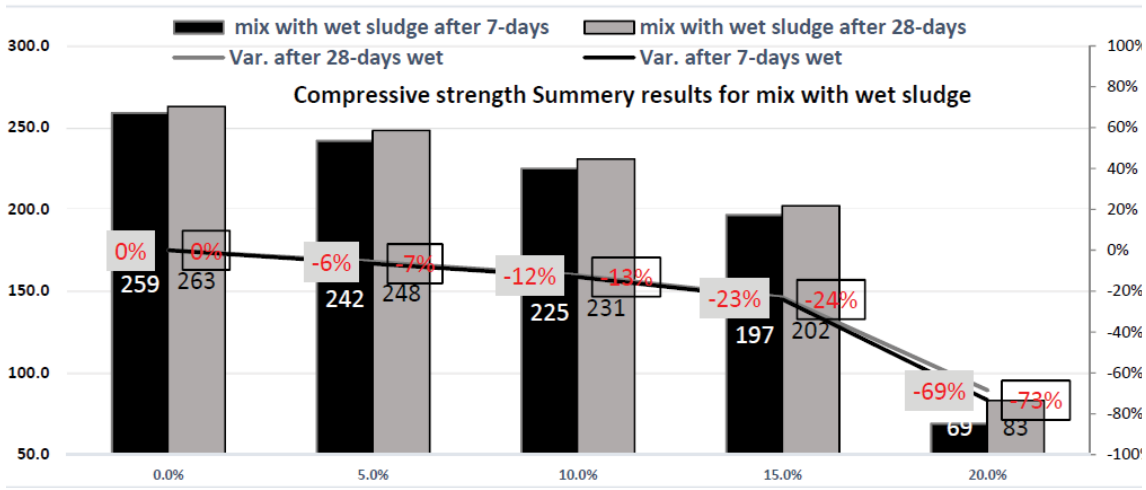
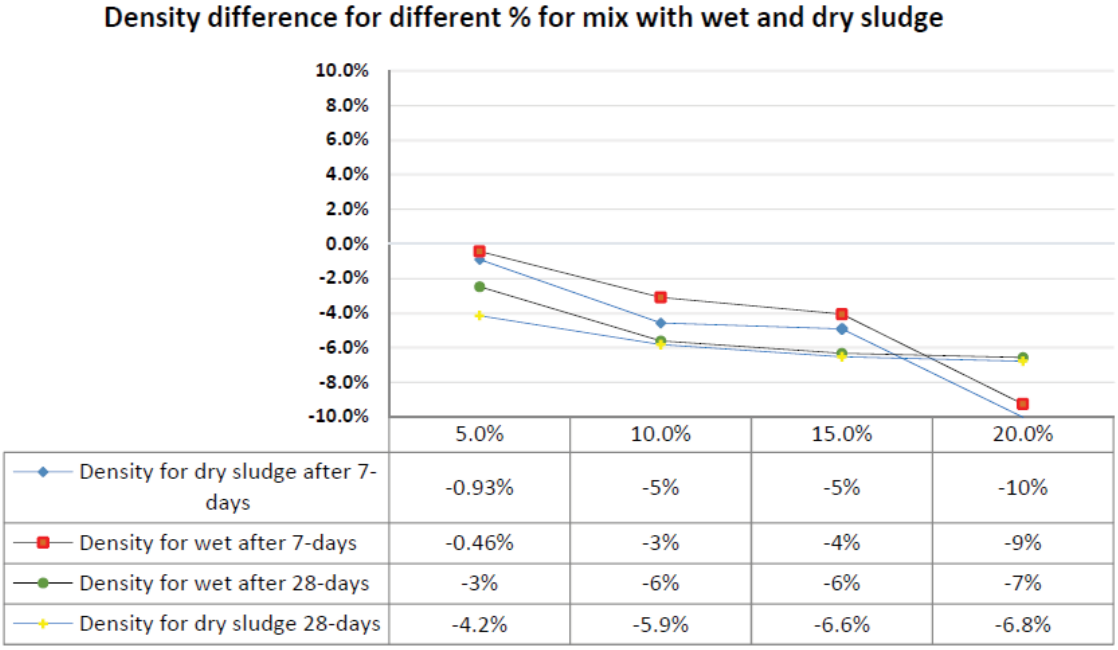


Figure 6: Slump test analysis for wet sludge results.



	5.0%	10.0%	15.0%	20.0%
Density for dry sludge after 7-days	-0.93%	-5%	-5%	-10%
Density for wet after 7-days	-0.46%	-3%	-4%	-9%
Density for wet after 28-days	-3%	-6%	-6%	-7%
Density for dry sludge 28-days	-4.2%	-5.9%	-6.6%	-6.8%

Figure 7: Density difference for different % for wet and dry sludge.

8. However, increasing the percentage of added wet sludge more than 5% decreased the workability of the mix around 2.25 cm difference than control mix and subsequently caused a reduction in the slump value obtained.

9. The results showed that 20% of cement weight for wet sludge led to a significant decline in compressive strength about 68.5% of control strength after 28-day age curing.

10. For wet sludge different percentages, the required drying period after pouring it in the mould increased with increasing the dry sludge percentages, Moreover for 20% wet sludge from cement weight it take about 10-days to be dried in order to remove it from the mould and prepare it for curing.

11. The adverse effect of wet sludge on concrete compressive strength increased as the slump value decreased. The compressive strength of concrete mix contained 5% sludge decreased by 5.7% after 28- days when the mix slump was 7 cm and 20% sludge decreased by 68.5% after 28-days when the mix slump was 4 cm.

12. The density of the concrete decreased in all cases with an increasing sludge content.

13. The reduction in density of sludge was higher when dry sludge was used than counterpart percentages for wet sludge.

14. In general, the rate of strength developed for all sludge concrete were lower compared to control mix without sludge.

15. The results indicated that due the reduced workability of

Concrete Mix	Compressive Strength after curing 7-days	Variance % after 7-Days	CompressiveStrength after	Variance% after 28-Days Slump Test (cm)	Slump Test	Variance (cm)
Normal mix	259	0	263.3	0	8	0
5% dry sludge	256	-1.2%	260	-1.3%	7	-1
10% dry sludge	239	-7.7%	242	-8.1%	6	-2
15% dry sludge	201	-22.4%	227	-13.8%	5	-3
20% dry sludge	94	-63.7%	101	-61.6%	3.5	-4.5
5% wet sludge	242	-6.6%	248.3	-5.7%	7	-1
10% wet sludge	225	-13.1%	230.7	-12.4%	5.5	-2.5
15% wet sludge	196.7	-24.1%	202.3	-23.2%	4.5	-3.5
20% wet sludge	69	-73.4%	83	-68.5%	4	-4

Table 7: Results Summary.

concrete mix with sludge content more than 10% could adversely affected the preparation of concrete Table 7.

References

1. Adeniji A (2004) Bioremediation of Arsenic, Chromium, Lead, and Mercury (1-43).
2. Ahmed MA, Diaz C, Faaij A, Gao Q, Hashimoto S, et al. (2007) Waste Management.
3. Alqam M, Jamrah A, Daghlas H (2011) Utilization of Cement Incorporated with Water Treatment Sludge, Jordan J Civil Eng 268-277.
4. Architektūra D, Statyba IR, Rozenstrauha I, Survila S, Krage L, et al. (2011) Recycling Possibilities of Sewage Sludge from Water Purification, J Sustainable Architecture Civil Eng 1: 1.
5. Commission E (2001) Disposal and recycling routes for sewage sludge Part 3 - Scientific and technical report.
6. Council N (2003) Nordic Council of Ministers Cadmium Review Nordic Council of Ministers Cadmium Review.
7. Dhunpath K (2001) Presence of protozoa and metazoa in activated sludge during favourable and unfavourable 2.
8. Eriksson E (2009) Organic substances in sewage sludge intended for agricultural land what do we know and where are the knowledge gaps? Background reports commissioned by Simon Lundeberg, Klimatbyrån 1-5.
9. Evans T, House A, Listons T, Road L (2011) Sewage sludge: Operational and Environmental Issues FR / R0001 Third Edition 44.
10. GS, AS, GE, HB. Chemical, physical and biological characteristics of sewage water (sludge and effluent).
11. Jamshidi M, Jamshidi A, Mehrdadi N (2012) Application of sewage dry sludge in concrete mixtures. Asian J Civil Eng 3: 365-375.
12. Matar M (2008) Use of wastewater sludge in concrete mixes A thesis submitted in partial fulfillment of the requirements for the degree of Submitted by: Supervisor.
13. Galal YGM (2012) Recycling of Treated Sewage Sludge in Sustainable Agriculture. Arab J Nuclear Sci Applications 45: 548-560.
14. German GTZ, Consult IPP (2002) Case study sewage sludge conversion in Egypt. German development agency.
15. Ghazy M, Dockhorn T, Dichtl N (2009) Sewage Sludge Management in Egypt : Current Status and Perspectives towards a Sustainable Agricultural Use, World Academy of Science, Engineering and Technol 49: 492-500.
16. Griswold W (2009) Human Health Effects of Heavy Metals, Center for Hazardous Substance Research 1-6.
17. Harrison EZ, Oakes SR, Hysell M, Hay A (2006) Organic chemicals in sewage sludges. Sci total environ 367: 481-97.
18. Hegazy BEE, Fouad HA, Hassanain AM (2005) Brick Manufacturing From Water Treatment Sludge And Rice Husk Ash. Australian J Basic Applied Sci 6: 453-461.
19. Hope J (1986) Sewage Sludge Disposal and Utilization Study. Washington State Institute for Public Policy.
20. Pirofski L, Casadevall A (2012) Q and A: What is a pathogen? A question that begs the point. BMC biol 10: 6.
21. Process AS (2003) Explaining the Activated Sludge Process. PIPELINE - Spring 14: 2.
22. Removal G (1994) Wastewater Technology Fact Sheet, United States Environmental Protection Agency.
23. Strauch D (1991) Survival of pathogenic micro-organisms and parasites in excreta, manure and sewage sludge. Revue scientifique et technique (International Office of Epizootics) 10: 813-46.
24. Systems L, Provide C, Treatment LW (1997) Lagoon Systems Can Provide Low-Cost Wastewater Treatment 8: 1-8.
25. Xu CC, Lancaster J (2007) Treatment of Secondary Sludge for Energy Recovery. hunderbay: Department of Chemical Eng.
26. Yusuf RO, Noor ZZ, Abba AH (2012) Use of sewage sludge ash (SSA) in the production of Cement and concrete - a review Moh'd Fadhil Moh ' d Din. Int J Global Environ Issues 12: 214-228.