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Investigating the Possibility of Using the Potential of Drilling Cuttings in Making Concrete in Order to Reduce Environmental Damage

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Abstract: - Oil drill cuttings (ODS) with different mineralogical characterizing in comparisons with other cement types. Physical, chemical, treated oil sands drill cuttings waste were interested. Oil sand drill cuttings waste represents one of the most difficult challenges for drilling wells. This article presents data on the physical/chemical used drilling fluids as well as produced drilling fluids as well as produced cuttings and irreparable image to the extenuate to the environment fresh and hardened properties for grouts incorporating the treated solid cuttings waste were evaluated the presented comparable results from the measured analyzed physicochemical and mineralogical data are useful information for furthering research on the suitability of ODC, wastes from oil and gas explorations, as partial replace.in this study the physical, chemical and mineralogical characteristics of the treated oil sands and maximum concrete qualification were investigated, and offers an innovative solution for recycle and reuse of treated oil sands drill cuttings waste (TOSW) in grout manufacture.

Keywords: oil drill cuttings, environment, drill cuttings, concrete qualification, grout manufacture.

1. Introduction

Utilizing Recycling materials in lightweight concrete brings many benefits such as economic savings. Approximately 25 billion tons of concrete are produced annually in the world, i.e. 3838 tons of concrete per person. In this study the reduction in aggregate consumption Reviewing the literature on the use of drilling cuttings was conducted to show the need to recycle drilling cuttings and techniques that can be used for sustainable development,

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improving the construction industry, environmental protection, and gaining economic benefits from the use of drilling cuttings.

Industrial-scale production processes often lead to the generation of different types of waste that must be properly managed to prevent or be unrelated to environmental issues. Proper waste management is important not only for health, environmental, and human concerns but also as a step towards sustainable development [9].

Sustainability analysis covers three aspects: environmental, economic, and social. Although the purpose of comparative sustainability analysis should be to quantify these three aspects, economic analysis is widely used to compare alternative processes. However, quantification of environmental and social aspects remains in the early stages of development. Despite attempts to quantify sustainability, very few of these three aspects can be observed. This is the most important problem in quantifying stability [10].

The biggest environmental concern about the production of concrete and cement is energy consumption. Cement production is one of the most energy-consuming industries. In this industry, about 6 million Btu per ton of cement is consumed in the mining, raw material transportation, and factory production stages alone. Given that cement makes up about 12% of the volume of concrete, 92% of the energy requirement in concrete production is related to cement [7]. Therefore, improving the desirable properties of concrete and, more importantly, increasing the durability of concrete structures will significantly contribute to reducing environmental damage.

Different technologies had been applied as a pre-treatment process to convert this oil sands drilling cuttings waste to a reusable product [20,24,10] Recently, an innovative technology (so called Thermo-mechanical Cuttings Cleaner (TCC) was developed for treating oil sands .drilling cuttings and recovering hydrocarbons[29] . In the TCC, waste is heated to a temperature just high enough to evaporate oil and water, which are then bought back to a liquid phase in separate condensers.

The increasing global demand of energy, on which many utilities of socioeconomic well-being of modern society are dependent, necessitates continuous sourcing of energy resource from which the conventionally sourced energy usage remains paramount [1,2] Among the fossil fuel sources, petroleum, the rock oil, is extensively consumed on a large scale, globally, for both domestic and industrial applications. This ensures fossil fuel extraction from this, however , are that exploration activities of petroleum from oil reservoir through drilling operations, lead to the generation of oil drill cuttings (ODC) as waste products[5-7].Treatments methods usually employed for ODC includes stabilizations-solidifications process, bioremediation, thermal desorption method,as well as vitrification/devitrification techniques[5-7-1G]

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Advancing from the business as usual (BAU, the normal execution of standard functional operations) to state-of-the-art technologies requires analysis tools since no universal solution exists for the management of drill cuttings and the multi-criteria nature of sustainability (Sikdar et al., 2012). In fact, the use of sustainability analysis as part of the decision-making process is becoming a usual practice early in process (or products) developments (e.g., Hallstedt, 2017). For organisations, sustainable strategies, allied to the three pillars of developments (economic, environmental and social) are a corporate and operational differential (Infante et al., 2013).

2. Methods

What is versatile characterization technique is Compositional Chemical Change Technique.

XRF which excites the elements present in the sample entails exposing to X-Ray light, which is different with XDF the presence amounts of minerals species in samples. Chemical analysis of hardened can provide a wealth of information about the mix constituents and possible causes of deterioration. Standard Methods in this Articles can be used to find the cement content and original waters. Which is made up four main compounds: Tricalcium silicate, dicalcium silicate, tricalcium aluminate, and a tetra- calcium alumino ferrite, The most important hydraulic constituents are Calcium silicates, upon mixing with water, the Calcuim silicates react with water molecules to forms calcium silicates hydrate (3 CaO. 2 Sio2. 3 H 2 O) AND Calcium hydroxides. The water of consistency, which is the basic element required to achieve a normal consistency for all tested cement paste mixtures incorporating different percentages of TOSW. The decreases of water consistency to gain solidification in concrete discussed later. TOSW as a partial replacement of cement reduces the hydration heat, this can be attributed to the dilution effect, once water and cement come in contact, cement wetting and hydration of free lime cause initial rapid heat liberation. Therefore, shrinkage and mass loss results can be explained here base on the two concurrently effects induced by TOSW addition: filling and diluting. characterizations of ODC samples were executed along with those of other cement replacement materials including Iran Cement (IC) conforming to longed- for cement.

2.1 Introducing concrete

In general, concrete refers to any material or compound that is composed of a cementitious adhesive. The adhesive is generally the result of the interplay of hydraulic cement and water. Concrete is one of the most widely used building materials, the main feature of which is its cheapness and availability of raw materials. The use of concrete can be seen in all construction works such as buildings, reservoirs, power plants, offshore structures such as piers, roads, water transfer routes, dams, etc.

Concrete is a material of two different phases, namely hydrated cement and rock aggregates, many of whose properties depend on the properties of each phase and their interface. For example, the resistance of concrete-to-concrete cancer, or the alkaline reaction of aggregates,

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is related to the phase of the aggregates, and carbonation occurs due to the reaction of air carbon dioxide with hydrated cement. Besides, the compressive and flexural strengths of concrete depend on the appropriate connection between these two phases (Ramezanipour and Shahnazari, 2005). There are many studies on improving the quality of concrete, most of which have examined changes in concrete composition (concrete mix design). However, there has always been a lot of attention paid to the use of additives as well as the replacement of conventional materials used in concrete with new materials. Nanomaterials are new materials that have improved the mechanical and physical properties of concrete. Due to their properties on very small surfaces, they can completely change the concrete world [7].

2.2 Density of fresh concrete

In yield measurements, the amount of air in the mix and the density of freshly compacted concrete are usually determined simultaneously. Density can be easily obtained by weighing freshly compacted concrete in a standard container of a specified weight and volume. The test method is described in ASTM C 138-81 and BS 1881. The volume of concrete can be obtained from the mass of its constituents if the density ρ is determined. The concrete yield for each module can be calculated from the values given in a module of a concrete mix. If the masses of water, cement, sand, and gravel in a module are W, C, Af, and Ac, respectively, the volume of compacted concrete is obtained from a module (yield) using the following equation.

$$V = \frac{C + A_f + A_c + W}{\rho}$$

Also, the content of cement (or mass of cement per unit volume of concrete) is obtained using the following equation:

$$\frac{C}{V} = \rho - \frac{A_f + A_c + W}{V}$$

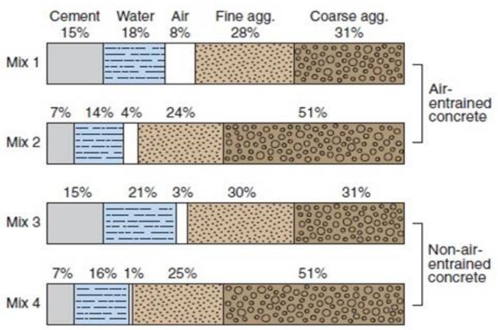

Figure 1. Concrete model

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The environment has been a major concern of human societies over the past decade. The construction industry is the largest consumer of materials, mining materials from the ground, and at the same time, the largest producer of waste and garbage entering the environment. As the building material of the century, concrete is the most widely used building material. From the perspective of environmental protection, production and consumption of concrete and its constituents, the interaction of concrete with the environment during its useful life, how concrete is degraded, and the return of degraded materials to nature and the environment is worthy of consideration. Ghorbani et al. (2009) presented a paper titled "Concrete and Environment" at the 3rd Conference of Environmental Engineering. In addition to examining the environmental characteristics of the concrete industry, they pointed to measures and solutions that are environmentally friendly and while reducing the harmful effects of the use of this industry in the environment, can provide the basis for its sustainable development.

In their master's thesis entitled "Feasibility Study of Using Drilling Cuttings in the Production of Asphalt Concrete", Hosseini et al. (2010) used raw drilling cuts in asphalt concrete.

In his master's thesis, Derakhshani (2014) used 13% by weight to make concrete floors.

2.3 Aggregate mixture gradation

According to Table 1, the water-cement ratio was 0.64 for the cement Type I - 525 and 0.59 for the cement Type I - 425. Considering 7% of air bubbles, the ratios of 0.29 and 0.24 were obtained, respectively. Here, cement with relatively high compressive strength compared to other types of cement, the ability to penetrate in concrete and stone cracks, and also better use to make precast concrete elements due to the acceleration of concreting and molding operations, such as Portland cement Type 1-525, was used. Cement Type 1-525 is classified in National Standard No. 389 of Iran as Portland cement type 1 with a strength class of 525 kg \ m^3.

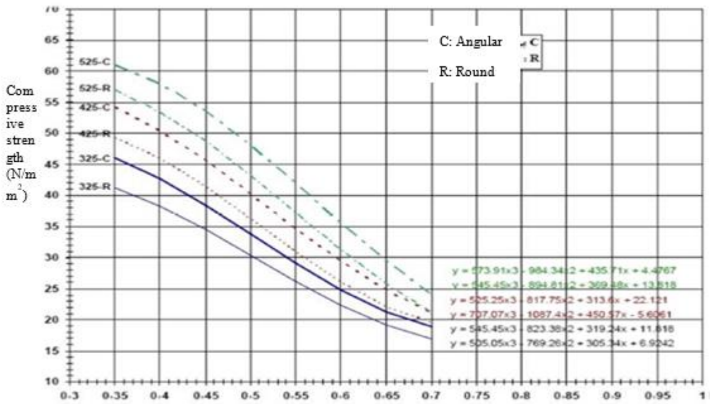

Figure 2. Gradation curve of a mixture of fine and coarse aggregates with a maximum size of 9.5 mm

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The maximum size of aggregates used in dry-pressed concrete curbs (DPCs) in this study was 9.5 mm. Therefore, the materials were graded in such a way that the fineness modulus (FM), which is equal to the sum of the percentage of materials retained on all the sieves, was 4.57.

2.4 Production and mixing of DPCs by Iranian Concrete Code (ABA) in plants is based on the following method.

2.4.1 Determining the free-water/ cement ratio

Figure 4 was presented since aggregate with more than 90% breakage is used in the construction of DPCs and due to the need for more water for broken materials and that the concrete slump in these curbs should be less than 1 cm. Therefore, the free water-cement ratio was 145 kg/m^3.

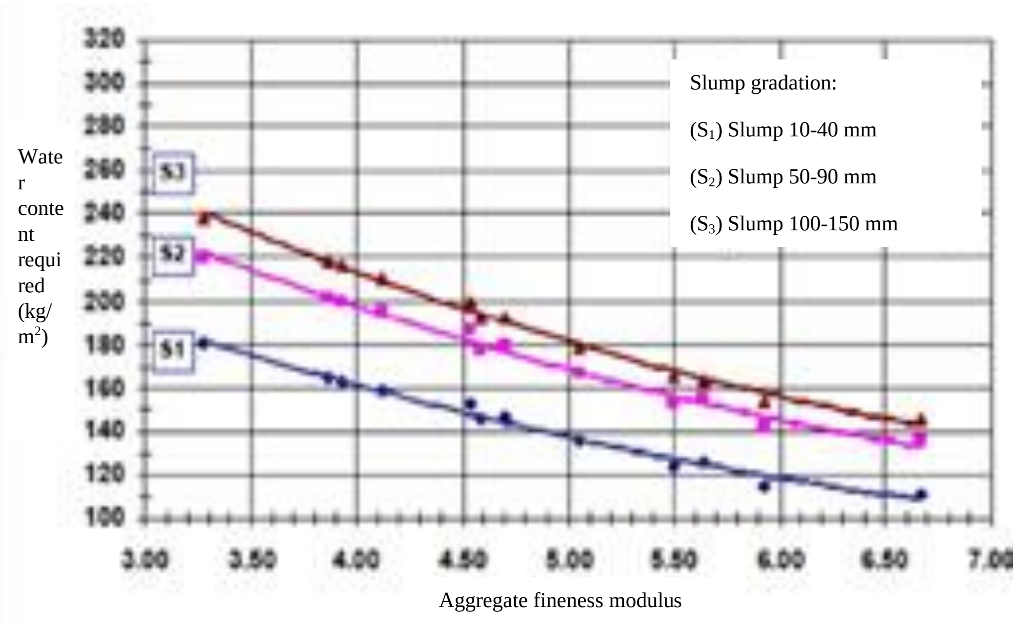

Figure 3. The water content required for concrete by plasticity and aggregate fineness modulus

For every percentage of air bubbles, 3.5 to 4% of water content must be reduced. So here, the water content was reduced by 25%, and it was finally 120 kg. The cement content was 415 kg for this water content and the water-cement ratio of 0.29. However, free-water content estimation curves are developed based on code 350. According to this code, for every 10 kg of change in cement content, 1.5 to 2 kg of mixed water should be changed in the same direction. Therefore, 12 kg of water had to be added to the obtained content. After this, the water content was finally 132 kg.

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2.4.2 Determining the cement content

The cement content was 455 kg/m^3 concerning the water-cement ratio of 0.29 and the free-water content of 132 kg.

2.4.3 Determining the aggregate content

The saturated surface-dry (SSD) aggregate weight of 1672 kg/m^3 was obtained using the absolute volume equation in ABA. 1003 kg of this content was sand and 669 kg was sand, taking into account the share of each aggregate (60% sand and 40% sand).

2.65 = aggregate weight [1000-142-132-95] = 1672

Table 1 shows the weighted values obtained from the Aba mix design (Source: Machine Sazi Tabriz Co.).

Table 1. The weighted values obtained from the ABA mix design

Air bubbles (٪)	Coarse-grained (kg)	Fine-grained (kg)	Water (kg)	Cement (kg)	Sample name
7	699	1003	132	455	A1-525

2.4.4 Plant production standards

- It is better not to break the sand and to be as round as possible. Broken sand increases cement consumption by up to 10% and has no technical-economic justification.
- The proper curing and mixing time by the mixer are 1.5 minutes unless it is ensured that a homogeneous concrete is obtained in less than this time.
- Bulk cement should be stored in metal warehouses or cement silos, not in construction warehouses, and the maximum storage period should not be more than 4 months.
- Broken sand can reduce cement consumption by up to 5% (Source: ISIRI-12728. Iran, I.o.S.a.I.R.o., Concrete Kerb units Specifications and Test Methods).

2.4.5 Precast concrete elements

The use of precast concrete elements is one of the techniques of using concrete, and concrete floors and curbs are among the most widely used of these elements. To achieve high quality in the production of concrete curbs, all factors affecting it, such as the properties of concrete materials, including aggregates, cement, water-cement ratio, construction method, compliance with technical principles during construction, curing, and environmental conditions must be

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considered. The average life of concrete curbs in most countries is about 15 years, but it is about 3 years in Iran. The life of these elements can be significantly increased and the waste of national materials and public costs can be prevented by spending small costs on production and observing technical principles in construction.

Due to the high cost of producing precast concrete elements, these valuable products are produced on a large scale, offered at very low prices, and reach mass production. Considering the low price and characteristics of concrete reinforced with drilling cuttings at the same time, it can be used in strategic structures with special uses such as the construction of non-load-bearing building materials on the most important urban structures such as precast curbs, floors, blocks, and walls, etc.

In this study, production techniques and factors affecting the production of precast materials such as floors and curbs with conventional materials using Aba were explained. How to produce concrete curbs and floors using drilling cuttings by the dry pressing method and their mix design were then investigated. In all these cases, the cement content, fine aggregate, coarse aggregate (drilling cuttings), water-cement ratio, number of air-entraining materials, and the percentage of water absorption of concrete, which indicates the durability of concrete, were considered. Studies on consumables and environmental conditions were first performed to obtain an optimal design for concrete curbs.

It was also found that five factors affect the production of concrete flooring for the production of concrete with very low corrosion effect, namely the production technique, mix design, surface materials, concrete curing, and the use of silica fume and other additives. Experience has shown that among production techniques, the dry pressing has the best resistance in the freezing cycle due to its integrity and pore coverage. However, for each production technique, a separate mix design is applied in which silica fume and other additives are used to increase abrasion resistance.

Like other concrete elements, the production of flooring requires proper curing to achieve the desired resistance. In this study, while introducing various concrete flooring processing techniques, the effect of choosing the type of technique on the ultimate strength of concrete flooring was not considered. However, the use of silica fume with fine particles and proper curing was recommended in the final stage of concrete floor production.

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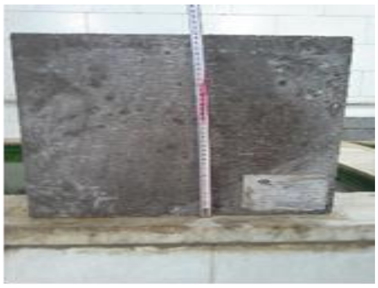

Figure 4. Floors produced with drilling cuttings

As mentioned earlier, an important factor in the destruction of concrete floors and curbs is the presence of large pores, resulting in high water absorption, lack of resistance to the freezing cycle, and low abrasion resistance. According to the conventional production techniques (dry pressing, wet pressing, and vibrating pressing), points should be considered about the material mix design, which are mentioned below.

The mix design of dry pressing in the plant with conventional materials is such that the materials are usually poured in two layers into the concrete mold. In working environments, the substrate layer of the floor is not exposed to destructive environmental and atmospheric conditions (pores in the surface cause water penetration, freezing, and as a result, cracks caused by the expansion of frozen water droplets during melting). Observance of some points in the mix design of materials by dry pressing technique empirically provides better strength. In this mix design, a mixture of 350 kg of cement type 2 per cubic meter with aggregate with a maximum diameter of 6 mm and a total moisture content of up to 8% is used in the substrate layer. In the surface layer, it is better to fill it and reduce the pores in mixing materials due to water absorption. According to the results of water absorption and freezing cycles on 100 flooring samples, it can be concluded that the optimal mix design of materials is used in the surface layer in the form of 350 kg of cement type 2 per cubic meter of material volume, calcareous aggregate with a maximum diameter of 1 mm, limestone powder, silica fume, and drinking water to the extent that the concrete slump does not shrink. It is worth noting that dry materials should be mixed for at least 90 seconds and then water added. Based on the experimental results in this study, the presence of silica fume in the mix design makes concrete more cohesive and more resistant to bending and abrasion.

The optimal mix design in this production technique is as follows experimentally: it is formed in 350 kg of cement type 2 per cubic meter, aggregate with a diameter of 10 to 25 mm, and water to the extent that the slump is above 16 cm. It should be noted that 7 to 15% of the cement used can be removed, and the conventional limestone powder in the market can be used instead.

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Plant mix design in mold (vibrating) production

The optimal mix design of materials in this production technique is as follows experimentally: per cubic meter of type 2 cement at a rate of 350 kg, aggregate with a maximum diameter of 10 mm, 5 w% of superplasticizer cement, silica fume, and water to the extent that the slump is between 6 and 10 cm. It should be noted that the presence of superplasticizer is critical due to the use of silica fume because silica fume increases the water required by concrete and thus reduces the strength due to high water absorption. The use of a superplasticizer is very effective to solve this problem and not need more water (Source: Machine Sazi Tabriz Co.).

2.4.6 Surface materials in concrete flooring

As mentioned before, in the working environment, the floor surface is connected to the ground with mortar. Side surfaces are also connected to the side floors. Therefore, only the floor surface is exposed to weather conditions, abrasion, and environmental pollution. Lack of resistance to environmental factors is the main reason for the degradation of concrete floors in the passages. In bilayer dry-pressed floors, the surface layer materials are generally different from the substrate layer. The fuller, more integrated, and with fewer pores and canals the surface layer, the less water and chemicals it absorbs from the environment, making it more resistant. This indicates the importance of using fillers in floor surface materials. However, technical points must be observed when using fillers along with other surface materials.

2.4.7 Mix design for the production of curbs and floors using drilling cuttings

In the production of concrete curbs and floors, the aggregates recycled from the destruction of concrete structures, recycled stone materials, and drilling cuttings, which are of three groups of rocks (igneous, metamorphic and sedimentary) based on geological information can be used. Different percentages of these rocks, which are the result of oil well-drilling waste, can be used in the production of concrete, and the water-cement ratio can be selected 0.45 and the ratio of aggregate to cement can be selected 4 to 1, depending on the mix design. Before using this type of material, their cost and efficiency should be carefully considered. Some of the factors that have led to the increasing use of these floors are their easy installation, fast construction, environmental compatibility, variety of shapes and colors, easy production, and low need for the outlay of foreign currency.

Floors are selected based on factors such as the amount of rainfall in the area, the amount of acid rain, the risk of sulfate penetration, and the amount and type of load passing through them. Another important factor for choosing the type of flooring is an adaptation to the geographical and climatic conditions of the region. Concrete floors have different types in terms of appearance, such as hexagonal flooring, grooved flooring, puzzle design flooring (Derakhshan, 2014).

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It is noted again that this study was conducted to use drilling cuttings in concrete floors and curbs instead of stone materials due to the increasing price of stone materials and drought that has reduced the extraction of river mines in recent years. Besides, the optimal use of these cuttings, and the burial and relocation of which require large expenditures for drilling companies, will be effective in preserving the environment, achieving sustainable development, and eliminating underground waste reservoirs.

2.4.8 Gradation of drilling cuttings

The purpose of the drilling cutting gradation test is to determine the exact percentage of materials retained and the passed through each sieve to determine which materials drilling cuts are to be used in concrete floor and curbs samples and to be examined and compared in the following conclusions. Standard sieves were used for gradation. For this purpose, the sample was first thoroughly mixed, and after drying, a suitable amount was selected according to the standard for the maximum nominal size of the material. After the initial weighing of the sample, sieves with appropriate hole sizes that can provide the required data were selected according to the characteristics of the rock material to be tested. The sieves were arranged from top to bottom in order of decreasing hole size. The whole sample was then placed on the highest sieve. The sieves were shaken by hand or shaker (mechanically) for a reasonable time, and the amount of material on each sieve was limited so that all particles could pass through the sieve and come into contact with the sieve holes several times. If the number of fine grains passing through the 4 or 16.3-inch sieve was high, gradation was performed in two phases to avoid test error. For this purpose, fine-grained materials passed through a 4-inch sieve were sampled according to the standard, and gradation was continued on sieves smaller than 4 inches. Finally, after determining the percentage of material retained and passing through each sieve, if the gradation was two-phase, the second phase was corrected compared to the first phase to obtain the percentage of passage for all sizes relative to the total. Graded materials, percentage of passing materials, and percentage of materials retained on each sieve are shown in the table and the gradation curve.

Table 2. Gradation of a sample of drilling cuttings

Sieve size	The weight retained	The percentage retained	The percentage passed
1.2 inch (12.5 mm)	395	9.875	90.125
3.8 inch (9.5 mm)	193	14.7	85.3
4 inch (4.75 mm)	278	21.65	78.35
8 inch (2.237 mm)	384	31.25	68.75

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30 inch (0.6 mm)	128.8	34.47	65.53
50 inch (0.3 mm)	588.93	49.19	50.81
100 inch (0.15 mm)	412.94	59.51	40.49
200 inch (0.075 mm)	510.28	72.267	27.733

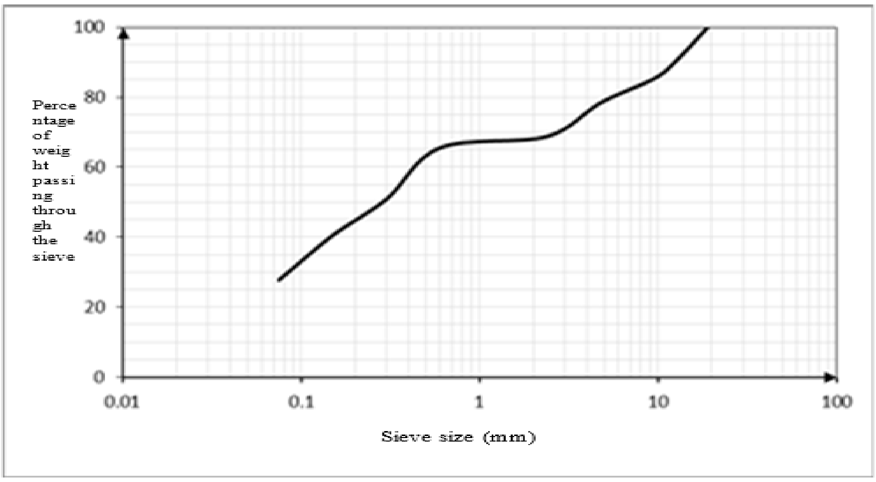

Figure 5. Gradation curve of drilling cuttings

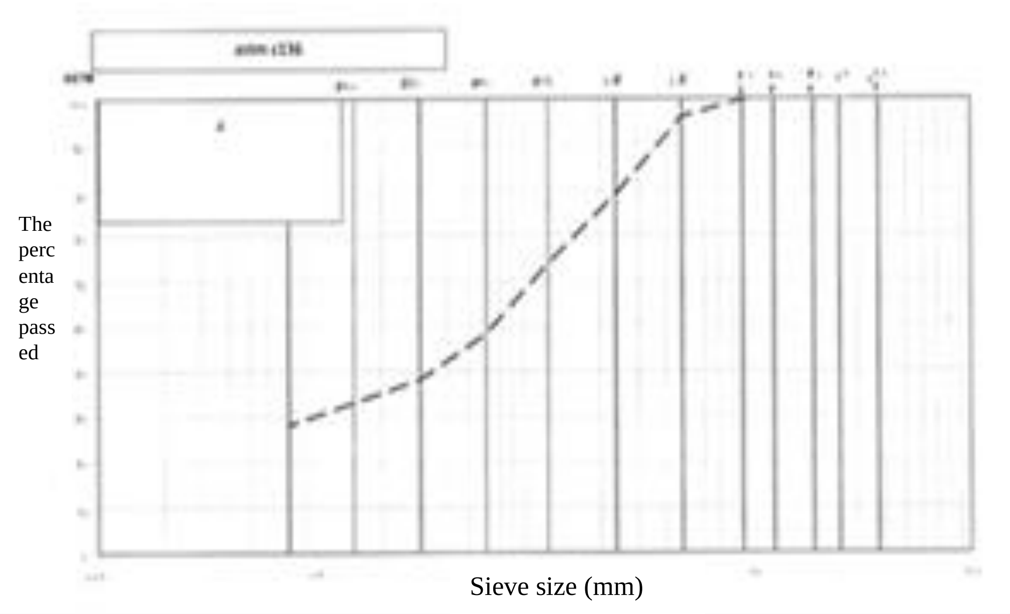

Figure 6. Drilling cutting size curve

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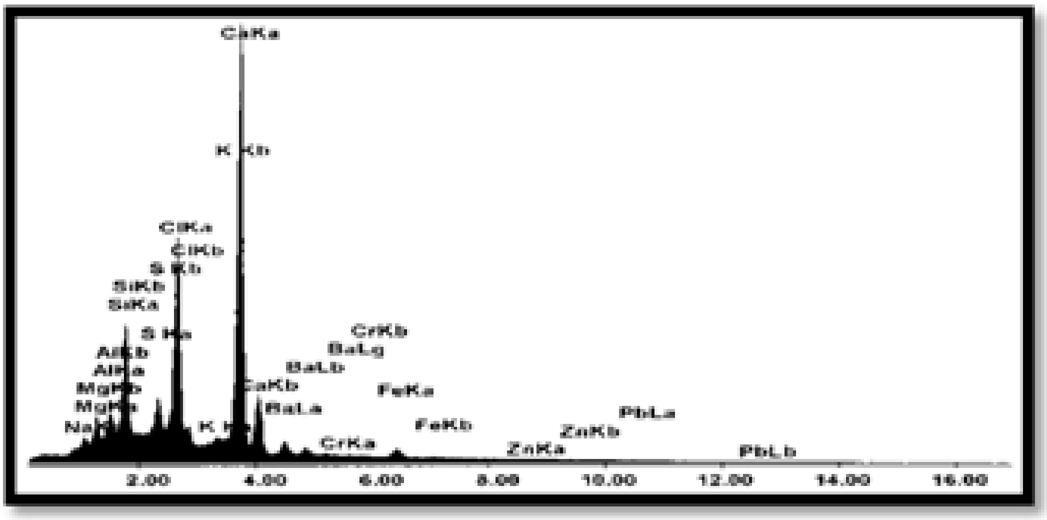

Figure 7. Chemical analysis curve of drilling cuttings

After presenting the production process of concrete curbs and floors in the plant and how to produce the elements, the production of concrete floors using drilling cuttings in the mixing design was described and compared with the floors produced in the plant. The following materials are used to fabricate concrete flooring:

First, the mix design and the production of conventional concrete were done with conventional materials, after grading sand and gravel and drying the materials.

1. 380 kg of cement type 5 1-525

2. 1700 kg of sand

3. 60-50 liters of water

4. 2 liters of superplasticizer

The above values are for the production of one cubic meter of concrete to produce concrete flooring.

The mix design and the production of concrete with drilling cuttings were done based on the following design after grading the materials obtained from drilling cuttings and drying them.

1. 350 kg of cement

2. 1800 kg of drilling cuttings

3. 195 kg of water

4. 2/3 liters of superplasticizer

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2.4.9 Weights of materials constituting one cubic meter of the concrete sample produced from drilling cuttings, in case the stone materials are completely dry (by weighting method)

Table 3 Concrete mix design with a standard cube sample with dimensions of 15 * 15 * 15 cm

Drilling cutting materials	Cement type 2	Construction site water (mixing water + water absorbed by the aggregates)	superplasticizer	Water-cement ratio (W/C)
1700	350	170 + 22 = 192	3	5/0

Table 4. Mix design specifications

Compressive strength of a cubic sample (kg/m^2)						Shrinkage (cm)	The percentage of air bubbles in concrete	Weight per unit volume of fresh concrete	Considerations
7 days			28 days						
197	200	202	256	262	266	2	2.5	2310	*

Table 5. Weight of materials constituting one cubic meter of the concrete sample made of sand 06

Drilling cutting materials (kg)	Cement type 2 (kg)	Construction site water (mixing water + water absorbed by the aggregates)	superplasticizer	Water-cement ratio (W/C)
1800	350	255	1.9	0.6

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Table 6. Mix design specifications

Compressive strength of a cubic sample (kg/m^2)						Shrinkage (cm)	The percentage of air bubbles in concrete	Weight per unit volume of fresh concrete	Considerations
7 days			28 days						
104	107	109	137	141	143	13		2100	*

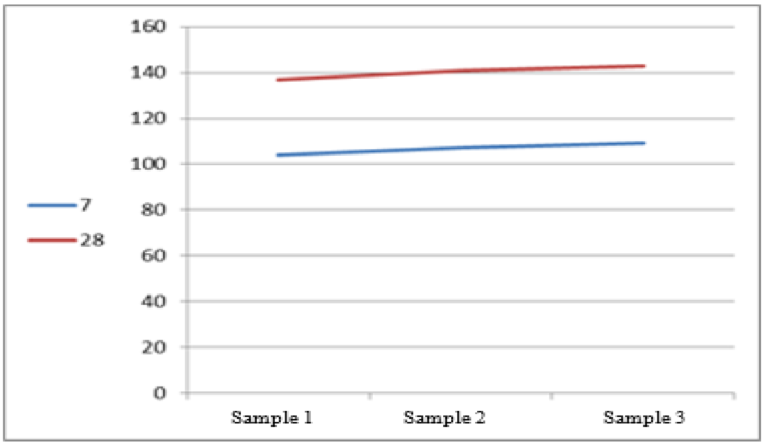

Figure 8. Compressive strength curve of the concrete sample with sand 06

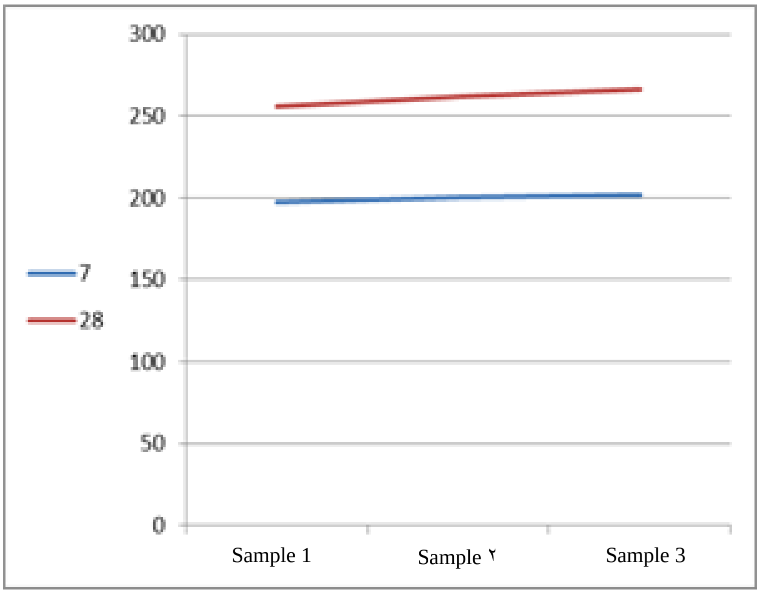

Figure 9. Compressive strength curve of the concrete sample with drilling cuttings

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3. Conclusion

In this study, 0.6% of the weight ratio of drilling cuttings was added to concrete. Further studies are recommended to use different percentages to obtain the optimal value, flexural and tensile strength, and abrasion resistance. From a managerial point of view, the construction of building materials using drilling cuttings to protect the environment requires long-term planning for future generations so that such reservoirs can be used for other purposes in the construction of rods and industrial infrastructure such as waste management reservoirs, oil and gas wells. The mix design of lightweight cement with water (W-C) should be such that it can be used the lower the amount of water, the better the strength of the concrete and can be used in other large projects such as dams, water sources, refineries, and water and wastewater treatment plants due to its high durability and impermeability. The use of silica fume and superplasticizer in the concrete mix design with drilling cuttings to seal the above materials will increase the durability and life of the concrete. It does not affect reducing compressive strength and will be an effective step towards sustainable development. Permeability is reduced by about 30% if the surface of concrete materials is sealed with permeable materials. The experimental design show that employing TOSW as construction can represent an interesting and viable alternative to final landfill disposal. Water of consistency of cement paste mixtures slightly decreases as the percentage of TOSW increases [20,21,22]. Complied data from the literature, expanded with calculated values, are represented to support the analyses and are a contribution to future studies and applications of the Methodology. The quality of the data used in the inventory directly influences the outcome of the comparative analysis. Thus, in practical applications of the proposed methodology, whenever available, field data should be used.

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