IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 4, April 2016.
www.ijiset.com
ISSN 2348 – 7968

The Potential Use of SSA and ISSA in Construction Field. A Review

Tan Yeong Yu, Doh Shu Ing[2], Chin Siew Choo[3] and Yap Hiew Thong[4]

[1] Faculty of Civil Engineering, University Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Kuantan, Pahang Darul Makmur, Malaysia.

[2] Faculty of Civil Engineering, University Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Kuantan, Pahang Darul Makmur, Malaysia

[3] Faculty of Civil Engineering, University Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Kuantan, Pahang Darul Makmur, Malaysia

[4] Faculty of Civil Engineering, University Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Kuantan, Pahang Darul Makmur, Malaysia

Abstract

Disposal of the sewage sludge is one of the major issue that been encounter most of the parties because it related to the environmental restrictions. Due to the heavy metals found in the sewage sludge, it is not permitted to dispose it in the soil or used as the fertilizer. Thus, investigation to use sludge in the construction field has been conducted. Sewage sludge which contain pozzolanic properties is used to replace cement, has been used to produce bricks, aggregates, ceramic and glass. Current cement production depended highly on non-renewable materials and requires high energy for production of which causes negative impact to the environment. Thus, sewage sludge which is renewable and environmental friendly could be used as alternative materials in the construction industry.

Keywords: *sewage sludge concrete, environmental friendly materials, chemical properties, physical properties.*

1. Introduction

Concrete is the most used material in the construction field amounting up to 10000 million tons yearly [1]. The most common cement in concrete production is Portland cement is known as hydraulic cement since it is to set and harden through reacting chemically with water under hydration process. In order to meet the increased demand, attention had been given identify or develop of the sustainable construction materials.

Disposal of human sewage has become a necessity for societies now a day. Sewage sludge was disposed to landfills and seawaters [2]. High amount of dry sewage sludge has been severe problem to the sewage treatment plant. It had been found out that each person had been produced 35 to 85 grams of solid sludge per day [3]. As the result, waste generation and management had become an international challenge resulting into increased environmental concern. Researchers has look into reusing and recycling waste materials into sustainable construction materials had turn up an alternative solution instead of waste disposal or land filling. Sewage sludge is one of the successful waste ingredients that used in the construction materials.

Due to the space limit for the landfills and increased of the environmental concerns for example groundwater pollution from landfills, odor emissions as well as soil contamination has simulated the investigation of alternative routes. As the result, sewage sludge had been used as the fertilizer and soil amendment [4]. However, the heavy metal inside the sewage sludge had reduced its function to the agricultural. The heavy metals such as Zinc (Zn), Copper (Cu), Nickel (Ni), Cadmium (Cd), Lead (Pb), Mercury (Hg) and Chromium (Cr) [5]. Even though sewage sludge tend to have heavy metals, but the concentration of the heavy metals are depends on their origins [6]. Table 1 indicates the global generation of the incinerated sewage sludge and sludge. According to the Table 1, it shows that there should be an alternative solution for the sludge disposal because the world is generate too much of sewage sludge.

Table 1: Global Generation of Incinerated Sewage Sludge ash (ISSA) and sludge

Country	Type	Amount/year	Source
Europe	Sludge	10.0×10^6 tons	Anderson (2002)[7]
United states	Sludge	7.0×10^6 tons	Anderson (2002)[7]
North America	ISSA	1.2×10^6 tons	Cyr *et al.* (2007)[8]
Japan	ISSA	0.5×10^6 tons	Murakami *et al.* (2009) [9]
Taiwan	Sludge	1.2 x 108 m^3	Chiou et al (2006)[10]

The solution to remove some of the heavy metals in the sewage sludge is going through incineration. Incineration process is able to destroy the organic compounds, minimize odors, greatly reduce volume of sludge and has calorific value. Due to the expected growth of the world population and also increase of the volume of the waste water indicates that sewage sludge ash will rise at a very fast pace in the future [11]. Since the area for the sludge ash disposal it had proved that the essential of reusing the sewage sludge in the production of the concrete.
In addition, sewage sludge adversely affects the durability of the concrete, because the heavy metal, lead (II) hydroxide $Pb(OH)_2$ and tin (II) hydroxide $Sn(OH)_2$, had retarded the setting time and hardening reaction of the concrete. As the result, the portion of the sewage sludge that used in the concrete had their own quantity due to its specification [12]. Reuse or recycling such waste manages to develop or produce sustainable construction materials as proved to be a very hand-on solution to disposal and environmental problems.

2. Current Research

Sewage sludge had been widely used in the construction field. the most popular is the sewage sludge ash, it had been used as the additive in the production of the construction materials such as mortars, concrete, brick, asphalt paving mixes, aerated concrete, lightweight and heat-insulating materials, ceramic tiles, ecocement and for soil stabilization [13,14,15,16,17,18]. The possible of using sewage sludge and sewage sludge ash as the construction and building materials had been provided a brand new solution of alleviating the sludge in significant quantity. Moreover this solution has provide economic and energy saving advantages. Thus the investigations of this field have been carried out worldwide to analysis the possibility of using sewage sludge as the construction materials.

2.1 Physical Properties

Sewage sludge can be considered as non-plastic material which does not acquire making-water to reach the satisfactory of plasticity of extension. Sewage sludge ash consider as silty-sandy materials which between the range of 1 to 100 μm [7]. Garces et al. (2008) [19] found that the particle size of the sewage sludge was below 250 μm and the loss of ignition (LOI) was 5-1%. The particle size of the sewage sludge ash is depending on the source, some sewage sludge ash may have a significant fraction of the size larger than 0.6 mm [20]. If the particle size is greater than 0.6 mm, the sewage sludge needs to undergo crushing and screening process. The average of moisture content of the sewage sludge is from 8-28%. The aim of process is to make sure the sewage sludge able to mix well with the cement and fill the voids of the concrete. While the density for the sewage sludge is from 2160 kg/m3 and 2280 kg/m3 [21]. Table 2 shows the summary of the sieve analysis of sewage sludge ash. From the Table 2 it recommended the size of the sewage sludge ash used in the concrete production is less than 0.3mm.

Table 2: Sieve Analysis of Sewage Sludge Ash

Sieve size (mm)	**Cumulative weight of retained (%)**			
	William (1976)[22]	**Chatveera *et al*. (2006)[23]**	**Matar (2008)[24]**	**Pavagadhi *et al.* (2015)[25]**
4.75	0.87	0	9.4	44.7
2.36	1.38	0	20.8	64.1
1.18	6.98	0	31.3	82.1
0.6	11.87	0	40.5	86.8
0.3	13.47	76.22	68.1	92.4
0.15	17.74	81.16	94.5	95.9
0.75	19.31	91.01	97.8	97.9
pan	100	100	100	100

2.2 Chemical Properties

Sewage sludge ash consist of the primarily of silica, iron and calcium. However, the compositions of the sewage sludge ash come with vary significantly. The quantities of the chemical compounds are greatly affected by the additives that introduced in the sludge conditioning operation at each area [20]. Table 3 show the variety chemical compounds with different percentage. The Table 3 present that there is variety percentage for the iron oxide (Fe_2O_3) from the range of 0.9 to 11.99. This is the reason of the sewage sludge had variation of color; the changes of the color form light brown to dark reddish brown [21].

Silica is one of the most important chemical compounds that control the durable and strength of the concrete. Thus the silica is required in the pozzolanic reaction to produce calcium-silica-hydroxide (C-S-H). So that higher amount of the silica oxide tends to create higher durable and strength of concrete. From the Table 3, it shows that the range of the silica oxide that available in the sewage sludge ash is more than 26 %. The function of the calcium oxide is one of the compounds that responsible in formation of silicates and aluminates of calcium. However, excess calcium oxide will make the concrete unsound and cause the cement to expand and disintegrate. From the Table 3, sewage sludge had quite low amount of calcium oxide.

Table 3: Chemical Compositions of Sewage Sludge Ash

Compounds	Park *et al.* (2003)[26]	Badr *et al.*(2012)[27]	Chatveera *et al*. (2006)[23]	Jamshidi *et al.* (2011)[65]
SiO_2	39.52	43.12	26.87	54.5
Al_2O_3	17.17	15.97	6.91	8.9
Fe_2O_3	11.99	5.26	3.17	0.9
Cao	7.16	5.56	3.2	7.3
MgO	2.13	0.85	1.51	2.1
K_2O	2.72	0.26	0.98	1.8
Na_2O	1.23	0.52	0.18	0.4
SO_3	1.97	1.49	3.92	-
LOI	7.31	26.79	25.5	21.3

2.3 Sewage Sludge in Brick Production

Alleman et al. (1984) [28] had developed bio-bricks by using the mixture of sludge with clay and shale. The range of the partial cement replacement is from 15-25% to create biobrick. Thus, the biobrick is exactly the same with the regular brick from its look, feel as well as smell [29]. Chin et al. (1998) [29] investigated the utilization potential of sludge and co-generation ashes generated by the paper industry in producing bricks. The specimens that they used were incinerating up to 1000oC. The products exhibit some good properties in term of water absorption as well as compressive strength. However, the brick only recommended for the non-load bearing spacing construction materials.

Chiang et al. (2000) [30] studied the potential use of dried sludge form waste water treatment plant with agricultural waste and rice husk ash in production of novel light weight bricks. The mechanical properties of the brick with the replacement of 40% by the rice husk exhibit a high strength required for the lightweight bricks by the Taiwan standards. In addition, the brick had been used as the construction materials under green building purpose. Moreover, the results of the Toxic Characteristics Leaching Procedure indicates the concentration of copper (Cu), Zinc (Zn), Chromium (Cr), Cadmium (Cd) and lead (Pb) in the bricks were lower than the allowable level that stated in the standard regulations.

Tay et al. (2002) [31] developed a novel brick using dried waste water sludge and clay. The compressive strength of the sewage sludge brick decreases as the increase of the sludge content in the concrete. It was recommended to replace dry sewage sludge with sewage sludge ash to solve the uneven texture and porosity. Thus, the maximum range for using the sludge ash is up to 50% and it also show positive result of it. The brick containing sludge ash shown to have higher strength compare to the sewage sludge. Moreover, the bricks which contain 10% of the sewage sludge ash tend to have strength as high as the normal clay brick. Yague et al. (2002) [32] introduced the dry pulverized sludge in the production of the prefabricated bricks by using 2% in to the prepared samples. It shows a significant increase in term of compressive strength, decrease in porosity as well as water absorption compare to the bricks that without sewage sludge.

Chih-Huang et al. (2003) [33] carried out the study to examine the bricks produced from industrial waste water treatment plant. The quality of the brick is depending on the sludge proportion and the incinerating temperature [33]. The strength of the specimens with up to 20% of the sludge content at the firing temperature between 960-1000oC manage to meet the requirement of the Chinese Standard. Cusido et al. (2003) [34] produced clay brick made from sewage sludge and forest debris. The product was lighter more thermal and acoustic insulating compare to the conventional clay bricks [34]. Abdul et al. (2004) [35] made the bricks from sewage sludge as the raw materials. It recommended the bricks which is more than 30% was not suggested to use as structural propose because it is high brittleness [35].

Cheng-Fang et al. (2006) [36] used water treatment sludge and bottom ash in the production of water permeable bricks. The product that content 20% of bottom ash which sintered at 1150oC show a very good characteristics in term of compressive strength, good water absorption and good permeability [36]. Moreover, the bricks can be used as water permeable, environmental friendly product such as pavement in the urban area.

Kung-Yuh et al. (2009) [37] created lightweight bricks by sintering mixes of dried water treatment sludge and rice husk. The addition of the rice husk to the brick is to increase the porosity of sintered specimens and increase sintering temperature which able to lead to the improvement in term of compressive strength [37]. The specimens which contain 15% of the rice husk incinerate at 1100oC able to produce low bulk density and higher compressive strength which follow by the Taiwan Building Code Standards. Luciana et al. (2011) [38], the bricks by using textile laundry wastewater sludge and clay had been proposed at year of 2011. The mechanical properties and water absorption from the experiment were satisfied with the Brazilian Legislation. The bricks with 20% of sludge content show the best mechanical properties and the leaching test conducted show the product is safe without any side effect to the user [38].

Joan et al. (2012) [39] examined the environmental effect of the use of bricks manufactured from sewage sludge. Sludge can be successfully incorporated with the bricks with the sludge addition from the range of 5-20% [39]. There is no significant adverse effect on the health of the user and environment when using the sewage sludge bricks. Badr et al. (2012) [64] explored the replacement of clay bricks using sludge, agricultural and industrial wastes for example rice husk ash and silica fume. The product contained 25% of silica fume and 50% of sludge show superiority over the normal conventional bricks [64].

Pavagadhi et al. (2015) [25] replace the soil with different percentage of sewage sludge from 10% to 50%. The water absorption decreased up to 20% replacement of soil by the dry sewage sludge. Thus the compressive strength of the bricks increased as the replacement of the sewage sludge increase. In addition, the brick which containing 20% of dry sewage sludge show the highest compressive among the others. Since the bricks had been replaced by the dry sewage sludge, it had greatly reduced the weight of the bricks and turns the products into light weight bricks [25].

2.4 Waste Sludge as Artificial Aggregate

The use of waste sludge in the artificial aggregate is considered as a new material. Tay et al. (2002)[31] showed that by using dried industrial sludge with low organic content and clay which were pulverized separately to fine size before mixing with water to form a paste. Thus, the resulting paste was then form into aggregate shape which then undergoes high temperature of incineration [31]. Two type of concrete was made by using artificial aggregate and granite aggregate. The compressive strength for the granite aggregate is 38 N/mm2, while compressive strength for artificial aggregate concrete had the range of 31-38.5 N/mm2. Moreover, the artificial sludge clay aggregate exhibit higher porosity and lower density compare to the granite aggregate.

Chou et al. (2006) [40] studied the potential of use of sintered sewage sludge and sludge ash combination for creating synthetic aggregate. The combination of sewage sludge ash and clay was better for the production of the normal weight aggregate. Thus, the mixture of 20% of sewage sludge tends to be more adequate to produce lightweight aggregate [40]. The production of lightweight aggregate by using incinerated sludge had shown to be in low conductivity and high fire resistance comparing to the ordinary concrete. Most of the artificial aggregates are used to produce moderate strength concrete. Sewage sludge ash had been used as a portion of fine aggregate in the production of hot mix asphalt paving. There is no visible difference between the pavement made by sludge ash and conventional materials. The percentage of the sewage sludge that used in the production of asphalt paving is 2-5%.

2.5 Waste Sludge as Cement-like Materials

Tay et al. (2002) [31] investigated the utilization potential of digested and dewatered sludge in the production of cement like materials. The sludge cement tends to have high water demand and proposed quick setting time compared to the ordinary cement [31]. Mortar cube strength it turn out the cement was possible to produce masonry cement. In addition, the product that produced had met the requirement of the ASTM standard.

Goh et al. (2003) [41] used pulverized sludge ash blended with cement in concrete mix. The sewage sludge was treated at 55oC to remove some of the organic materials. The ash then undergoes pulverized process till 150 μm, and then incorporated with the cement. The result show the workability of the concrete increase as the ash gets finer. The specimens tested at the day 28 for the concrete cube that made with 10% sludge ash was similar with the ordinary concrete. However, as the sludge content increased up to 40% the strength drop dramatically by 50% [41].

Monzo et al. (2004) [42] investigated the potential use of sewage sludge pellets (SSP) as replacement in raw mix formulation in manufacturing process of Portland cement. The mortar that containing 15% of sewage sludge ash tend to show a similar compressive strength to the reference mortar. However, the percentage of the sewage sludge ash increased up to 30%, it showed a significant drop of its compressive strength (Monzo et al, 2004). Besides that, 11% of the cement clinker dry weight was replaced with the sewage sludge pellets, it present no significant difference or problem compare to the cement that made with normal cement clinker.

Arlindo et al. (2004) [43] examined the potential use of sewage sludge treated at different temperature as replacement material of cement in mortar preparation. The sludge was dried at 105oC and used as a partial replacement of cement by 20%. Thus, there was another trial by using the treated sludge which is incinerated at 450oC, 700oC and 850oC. All of the treated sludge was used as the partial replacement of the cement by 5% and 10%. The presence of the treated sludge caused the reducing of the compressive strength in the mortar.

Yiming et al. (2012) [44] studied the effects of dried sewage sludge as an additive on cement property in the process of clinker burning. The compressive strength of the specimens was slightly lower than the plain paste [44]. Moreover the leaching result for the specimens was within the Chinese Standard during the current stage.

2.6 Waste Sludge in Concrete Mixtures

Yaque et al. (2002) [32] studied the durability of concrete samples with sludge as additive to concrete to evaluate long term performance. The specimens were subjected to the accelerated attack which is the wet-dry cycles and sea water, accelerated aging in as autoclave and accelerated carbonation. The sewage sludge concrete proposed the same durability of the reference concrete [32].

Valls et al. (2005) [45] studied the potential usage of dry sludge as additive in concrete. The sewage sludge was undergoes drying process to reduce the humidity to a certain limit and remove the microorganisms inside it. After that the dried sewage sludge was act as the fine aggregate which replace at 0-10%. The sewage sludge concrete able to bring some beneficial to it in term of binding properties, thus the sludge components were stable. Moreover, the quantity of the leachable of heavy ions was greatly reduced compared to the free dry sludge [45]. The compressive strength of the concrete decrease gradually when increasing of the sewage sludge content.

Kartini et al. (2015) [46] investigated the performance of the concrete when using incinerated domestic waste sludge powder in the concrete mixture. The percentage of the domestic waste sludge is from the range of 3-15% with different water binder ratio of 0.60, 0.55 and 0.40 for Grade 30, Grade 40 and Grade 50. The performance of the domestic waste sludge powder concrete is judge in term of compressive strength, water absorption, water permeability and rapid chloride ion penetration [47,48]. The compressive strength of the domestic waste sludge powder concrete decrease when increase the replacement of the sludge powder. Besides that, the water absorption for the domestic waste sludge powder concrete tends to have higher water absorption ability compare to the Ordinary Portland Cement concrete. However, the average water absorption value for the sludge concrete still under accepted range that stated in the British Standard [49]. However, Ordinary Portland Cement control concrete possess more permeable than the sludge concrete Grade 40. While Grade 50 shows higher depth of penetration compare to other types of concrete specimens. For the case of the resistance to chloride ion penetration was measured by the charge coulomb drastically enhanced resistance to chloride permeability with incorporation of domestic waste sludge powder concrete which up to 15%. This indicated that the presence of the sludge will have a lower coefficient of permeability.

2.7 Waste Sludge Water Used in Concrete Mixtures

Chatveera et al. (2006) [23] used sludge water to produce concrete instead of normal tap water. The replacement of the sludge water to the tap water is from 0% to 100%. For the case of compressive strength of the concrete mixed with sludge water is in the range of 85-94% of the normal plain concrete. In addition, the bond strength between cement paste and aggregate is weaker when increasing the volume of sludge water as the tap water replacement. Thus it also increases the water-cement ratio. However, by using sludge water in the concrete mixtures it has an adverse effect on drying shrinkage as well as resistance to acid attack of the concrete.

Ghusain et al. (2003) [50] prepared the concrete specimens by using vary type of water. The types of water that used in the study are tap water, preliminary treated water, secondary treated wastewater and tertiary wastewater [50]. There is no effect for the density and concrete slump. The specimens that produced by preliminary treated wastewater and secondary treated wastewater are found to have lower compressive strength, slower strength development higher setting time and higher corrosion potential than the specimens made from tap water and tertiary wastewater. In addition, the concrete specimens that produced from the tertiary wastewater tend to have highest compressive strength compare with all specimens.

Roccaro et al. (2015) [51] used the wastewater treatment plant water in the production of the concrete. The sewage sludge water can be used as the partial replacement or total substitution of water in the production of the concrete. This is because there is no significant reduction for the compressive strength of the specimens. Besides that, the environmental compatibility was accomplished based on the toxicity properties leaching procedures.

2.8 Waste Sludge in Ceramic and Glass Production

Suzuki et al. (1997) [52] produced ceramic samples by adding limestone to incinerated sewage sludge ash. The sewage sludge ash was acted as the fine dust in the production which able to incorporated with other ceramic paste materials. The sample contains 50% of the sludge ash had the strength, acid resistance as well as absorption coefficient similar with the normal ceramics.

Ferreira et al. (2003) [53] showed there was minimum diffusion value of the heavy metals by using sludge ash to produce ceramics. Montero et al. (2009) [54] investigated the usage of sludge and the effect of its properties in ceramics. There were two types of sewage sludge added to the clay which was urban sewage sludge and marble sewage sludge. The ceramics that contain sewage sludge tend to have great reactivity and manage to react easily with the clay minerals and quartz [54].

Joan et al. (2011) [55] investigated the use of sewage sludge in building industry to produce a lightweight clay ceramics. The final creation tends to had low thermal conductivity. According to the leaching test, the leachate contain high amount of hazardous metals even undergoes the thermal treatment process [55]. Martinez-Garcia et al. (2012) [56] used sludge to substitute clay in a ceramic body at different percentage content replaced clay. The specimens that contain 5% of the sewage sludge propose good compressive strength, water absorption and water suction [56].

Zhikun et al. (2015) [57] studied the glass-ceramic that made by recycling of incinerated sewage sludge ash. The materials undergo two stages of sintering cycle which is nucleation stage and crystallization stage. The parent glasses were subjected to various temperature and time level [57]. While the glass-ceramic crystallized at 945oC for 2 hours show the optimal properties of density of 2.88 ± 0.08 g/cm3, compression strength of 247 ± 12 MPa, bending strength of 118 ± 14 MPa and water absorption of 0.42 ± 0.04. Moreover, the leaching concentration of the heavy metals was far lower than the requirement by the Environmental Protection Agency (EPA).

Besides that, sewage sludge ash able to convert into glasslike material under melting process. The melting point to turn sewage sludge ash into glasslike ingredients was above 1300oC [53].

2.9 Pozzolanic Activity of Sewage Sludge Ash

Pozzolanic activity can be defined as a siliceous and aluminous materials which, in itself, possesses little or no cementitious value but which will, finely divided from in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [58]. There are two major method can be used to analysis the pozzolanic materials which is direct and indirect technique. Direct methods is to measure the changes trend of the calcium hydroxide (Ca(OH)2) concentration as the pozzolanic reaction carry out such as Frattini test [59]. Thus the indirect method is to analysis the physical property of pastes linked to the pozzolanic reaction such as Strength Activity Index (SAI) [60].

Donatello et al. (2010) [61] investigated the effect of milling and acid washing on the pozzolanic activity of incinerator sewage sludge ash. The milling sewage sludge ash can improved the pozzolanic activity when the Strength Activity Index (SAI) and Frattini Tests were applied. The water requirements were reduced after the dry milling from 1.16 to 1.00. The finding showed there is more water being adsorbed onto the outer surface of the sewage sludge ash particles. However, the increment of the overall water of the sewage sludge ash was not significant due to the limited additional outer surface provided by grinding. Thus the total amount of water that being absorbed in the pores of the sewage sludge ash was nearly constant due to the grinding process which does not increase the pore surface area of the ash. Pan et al. (2003) [16] investigated the reusing sewage sludge ash as adsorbent for copper removal from wastewater. The compressive strength of the sewage sludge concrete can be increased by increasing the fineness of the sewage sludge ash. This is because fineness of the sewage sludge ash able to improve the pozzolanic activity of the sewage sludge ash. It involved grinding process as well as increases the outer surface of the sewage sludge ash particles.

Tantawy et al. (2012) [62] evaluated the pozzolanic activity of sewage sludge ash. There involve silica fume and sewage sludge ash in the study. The temperature of the incineration of the silica fume and sewage sludge ash are from the range of 500-950oC. Both of the materials treated with lime at 100oC for 16 hours. According to the result showed there was a descending order of the weight losses for silica fume larger than sludge ash incinerated at 800 oC > 950 oC > 650 oC. From the result obtained silica fume proposed higher pozzolanic activity compare to the sewage sludge due to the very fine amorphous silica particles. However the sewage sludge ash which incinerated at 800oC indicated highest pozzolanic activity and adsorption capacity compared to other sewage sludge ash specimens. This can be concluded that incinerated at 800oC able to activate the pozzolanic activity of the ash. While the temperature increased, it enhances the crystallization of amorphous silica and reduces the pozzolanic activity and adsorption capacity of the sewage sludge ash. Moreover, based on the economic point view incinerate the sewage sludge ash at 800oC is better than any higher temperature.

Drazen et al. (2015) [63] studied the reuse of sewage sludge which problems and possibilities. Based on the result acquired found out that the optimum incineration temperature of the sewage sludge is 800oC, this is because above 800oC it had the tendency to increase the crystallization and weakening of the pozzolanic activity of the sewage sludge ash [63]. Besides that, the particles size for the sewage sludge ash should increase the fineness in order to extend the binding time and settling time. Thus, the water absorption had increased due to the larger total fine surface area of the particles. As the result the pozzolanic activity of the sewage sludge ash had increased and developed of higher pressure strength of the resulting concrete in term of compressive and flexural strength.

3. Discussion

The application of using the sewage sludge that capable in the construction field has been proven by difference researchers in various methods. It is a solid evident that the most favorable to use the sewage sludge is in the production of eco-bricks. It had been started in the year of 1984. Thus, the least interested so far for the sewage sludge is in the production of ceramic and glass. Moreover, various tests had been carried out to analysis the performance of the concrete. The major properties had been done by researchers are compressive strength and water absorption. Thus, the leaching of heavy material by the sewage sludge had been take as serious concern when deal with the environmental issue. It clearly shown that, the incinerated sewage sludge show a good pozzolanic properties when it heated up at the temperature 800oC. However, when the temperature goes beyond the 800oC, the sewage sludge had the tendency to increase the crystallization and decrease the pozzolanic properties of it. The application of using sewage sludge is one of the new options in the construction industry which do not consume high energy compare to the firebricks. As the result, the emission of the carbon dioxide can be greatly reduced by replacing with the sewage sludge product. Moreover, more study had been done in the different use of the sewage sludge in the production of the construction materials. However, there is less analysis on the structural part which is involving sewage sludge. While the famous range of replacing the cement or fine aggregate in the concrete production is from 10-30%. Thus, the most acceptable result is 10%. Since the sewage sludge is one of biggest waste product that had been used as the waste disposal or landfill. By using the sewage sludge in the construction field can be consider as materials which is good in term if economical and environmentally.

4.0 Conclusion

This review paper shows the usage of the sewage sludge in the construction field from the early century till now. It shows that sewage sludge had the potential to replace the partial cement in the production of the concrete since it had high pozzolanic properties. Besides that, the water that supply by the wastewater treatment plant able to use as partial or total substitution of the water in the production of the concrete. As the result it can be concluded that the potential of using the sewage sludge in the construction area is one of the alternative solution to create useful material instead of disposed of the sludge which may involve huge amount of cost in the complexity of the treatment. Moreover, there is no significant reduction of the mechanical properties of the concrete by using sewage sludge in the production. Besides that, economic and environmental are most essential factors involve in the construction field had increase the tendency of using the waste product in the field. By using the sewage sludge had provide the finest solution to the waste problem and able to promote eco-friendly by reducing the cost of the raw materials.

References

[1] Glavind, M. Sustainability of cement, concrete and cement replacement materials in construction. In Sustainability of Construction Materials, Ed. Khatib, WoodHead Publishing in Materials, Great Abington, Cambridge, UK. 2009. pp120-147.

[2] Odegaard, H., Paulsrud, B. and Karlson, I. Wastewater sludge as a resource: sludge disposal strategies and corresponding treatment technologies aimed at sustainable handling of wastewater sludge. Water Science and Technology.Vol. 46, 2002, pp 295-303.

[3] Jamshidi, A., Mehrdadi, N. and Jamshidi, M. Application of sewage dry sludge as fine aggregate in concrete. Journal of Environmental Studies. Vol. 37, 2011, pp 59.

[4] Casado-Vela, J., Selles, S. and Navarro, J. Evaluation of composted sewage sludge as nutritional source for horticultural soils. Waste Management. Vol. 26, 2006, pp 946-952.

[5] Hsiau, P. C. and Lo, S.L. Extractabilities of heavy metals in chemically-fixed sewage sludges. Journal of Hazardous Materials. Vol. 58, 1998, pp 73-82.

[6] Fytili, D. and Zabaniotou, A. Utilization of sewage sludge in eu application of old and new methods-a review. Renewable and Sustainable Energy Review. Vol. 12, 2008, pp 116-140.

[7] Anderson, M. Encouraging Prospects for recycling incinerated sewage sludge ash (ISSA) into clay-based building products. Journal Chemical Technology Biotechemical. Vol. 77, 2002, pp 352-360.

[8] Cyr, M., Coutand, M. and Clastres, P. Technological and environmental behavior of sewage sludge ash (SSA) in cement-based materials. Cement Concrete Resources. Vol. 37, 2007, pp 1278-1289.

[9] Murakami, T., Suzuki, Y., Nagasawa, H., Yamamoto, T., Koseki, T. and Hirose, H. Combustion characteristics of sewage sludge in and incineration plant for energy recovery. Fuel Process Technology. Vol. 90, 2009, pp 778-783.

[10]Chiou, I. J., Wang, K. S., Chen, C.H. and Lin, Y.T. Lightweight aggregate made from sewage sludge and incinerated ash. Waste Management. Vol. 26, 2006, pp 1453-1461.

[11]Lundin, M., Olofsson, M., Pettersson, G. and Zetterlund, H. Environmental and economic assessment of sewage sludge handling options. Resource Conservations Recycling. Vol. 41, 2004, pp255-278.

[12]Valls, S., Yague, A., Vazquez, E. and Mariscal, C. Physical and mechanical properties of concrete with added dry sludge from a sewage treatment plant. Cement and Concrete Research. Vol. 34, 2004, pp 2203-2208.

[13]Monzo, J., Paya, J., Borrachero, V. and Corcoles, A. Use of sewage sludge ash (SSA)-cement admixtures in mortars. Cement and Concrete Research. Vol. 26, 1996, pp1389-1398.

[14]Wang, K. S., Chiou, I. J. Chen, C. H. and Wang, D. Lightweight properties and pore structure of foamed material made from sewage sludge ash. Construction and Building Materials. Vol. 19, 2005, pp 627-633.

[15]Dunster, A. M. Incinerated sewage sludge ash (ISSA) in autoclaved aerated concrete (AAC). Characterization of Mineral Wastes, Resources and Processing. 2007.

[16]Pan, S.C., Lin, C.C and Tseng, D.H. Reusing sewage sludge ash as adsorbent for copper removal from wastewater. Resources Conservation Recycle. Vol. 39, 2003, pp 79-90.

[17]Chen, L. and Lin, D.F. Stabilization treatment of soft subgrade soil by sewage sludge ash and cement. Journal of Hazadous Materials. Vol. 62, 2009, pp321-327.

[18]Devant, M., Cusido, J. A., Soriano, C. Custom formulation of red ceramics with clay, sewage sludge and forest waste. Applied Clay Science. Vol. 53, 2011, pp 669.

[19]Garces, P., Perez, C.M. and Garcia-Alocel, E. Mechanical properties and physical properties of cement blended with sewage sludge ash. Waste Management. Vol. 28, No. 12, 2008, pp 2495-2502.

[20]Mahak, B., Titiksha, R. and Nilam, M. Use of sewage sludge ash in replacement of stone dust in concrete pavement. Bachelor of Engineering. Thesis. VVP Engineering College, Rajkot. 2015.

[21]Halliday, J.E., Jones, M.R., Ravindra, K.D. and Thomas, D.D. Potential use of UK sewage sludge ash in cement-based concrete. Waste and Resources Management. Vol. 165, 2012, pp 57-66.

[22]William, K.F. Digested sewage sludge: characterization of a residual and modeling for its disposal in the ocean off southern California. Report. EQL Report No. 13. 1976

[23]Chatveera, B., Lertwattanaruk, P. and Makul, N. Effect of sludge water form ready-mixed concrete plant on properties and durability of concrete. Cement and Concrete Composites. Vol. 28, 2006, pp 441-445.

[24]Matar, M. Use of wastewater sludge in concrete mixes. Master of Science in Design and Rehabilitation of Structures. Thesis. The Islamic University of Gaza. 2008.

[25]Pavagadhi S., Divyang, B. and Vishal, K. Use of sewage sludge waste as ingredient in making of brick. Bachelor of Engineering. Thesis. VVP Engineering College, Rajkot. 2015.

[26]Park, Y.J., Moon, S.O. and Heo, J. Crystalline phase control of glass ceramics obtained from sewage sludge fly ash. Ceramics International. Vol. 29, 2003, pp 223-227.

[27]Badr, E.D.E.H., Hanan, A.F. and Ahmed, M.H. Incorporation of water sludge, silica fume and rice husk ash in brick making. Journal of Advance Environmental. Vol. 1, 2012, pp 83-96.

[28]Alleman, J. E. and Berman, N. A. Constructive sludge management: Biobrick. Journal of Environmental Engineering. Vol. 110, 2984, pp 301-311.

[29]Chin, T. L., Hui, L. C., Wen-Ching, H. and Chi, R. H. A novel method to reuse paper sludge and co-generation ashes from paper mill. Journal of Hazardous Material. Vol. 58, 1998, pp 93-102.

[30]Chiang, K. Y., Chou, P. H. and Chien, K. L. Novel lightweight building bricks manufactured from water treatment plant sludge and agricultural waste. A case study in Feng-Chia University, Tai-Chung, Taiwan. 2000.

[31]Tay, J. H., Show, K. Y., Hong, C. Y., Chien and Lee, D. J. Potential reuse of wastewater sludge for innovative applications in construction aggregates. Water Scientific Technology. Vol. 50, 2002, pp 189-196.

[32]Yague, A., Valls, S., Vazquez, E. and Cushion, V. Use of dry sludge from waste water treatment plants as an additive in prefabricated concrete bricks. Construction Material. Vol. 52, 2002, pp31-41.

[33]Chih-Huaung, W., Deng-Fong, L., and Pen-Chi, C. Utilization of sludge as brick materials. Journal of Advance Environmental. Vol. 7, 2003, pp 679-685.

[34]Cusido, J.A., Cremades, L. V. and Gonza'lez, M. Gaseous emissions form ceramics manufactured with urban sewage sludge during firing processes. Journal of Waste Management. Vol. 23, 2003, pp 273-280.

[35]Abdul, G. L., Azni, I., Calvin, H. K. W., Abdul, A. S., Megat, J., Noor, M. M. and Aminuddin, M.B. Incorporation of sewage sludge in clay bricks and its characterization. Journal of Waste Management. Vol. 22, 2004, pp 226-233.

[36]Cheng-Fang, L., Chung-Hsian, W. and Hsiu-Mai, H. Recovery of municipal waste incineration bottom ash and water treatment sludge to water permeable pavement materials. Journal of Waste Management. Vol. 26, 2006, pp 970-978.

[37]Kung-Yuh, C., Ping-Huai, C., Ching-Rou, H., Kuang-Li and Chris, C. Lightweight bricks manufactured from water treatment sludge and rice husks. Journal of Hazardous Material. Vol. 171, 2009, pp 76-82.

[38]Luciana, C. S. H., Carla, E. H., Miria, H. M. R., Nora, D. M., Celia, R. G. G. T. and Rosangela, B. Charaterization of ceramic bricks incorporated with texile lauhdry sludge. Journal of Ceramics International. Vol. 28, 2011, pp 951-959.

[39]Joan, A.C. and Lazaro, V.C. Environmental effects of using clay bricks produced with sewage sludge: Leach ability and toxicity studies. Journal of Waste Management. Vol. 32, 2012, pp 1201-1208.

[40]Chou, I.J., Wang, K.S., Chen, C.H. and Lin, Y.T. Lightweight aggregate made from sewage sludge and

incinerated ash. Journal of Waste Management. Vol. 26, 2006, pp 1453-1461.
[41]Goh, C.C., Shoe, K.Y. and Cheong, H.K. Municipal solid waste fly ash as a blended cement material. Journal of Material Civil Engineering. Vol. 15, 2003, pp 513-523.
[42]Monzo, J., Paya, J., Borrachero, M.V., Morenilla, J.J, Bonilla, M. and Calderon, P. Some strategies for reusing residues form waste water treatment plant: Preparation of building materials. Proceeding of the Conference on the Use of Recycled Material in Building and Structures. Barcelona, Spain. 2004.
[43]Arlindo, G., Ana, M.E. and Martha, C. Incorporation of sludge from a water treatment plant in cement mortars. Proceeding of the Conference on the Use of Recycled Material in Building and Structures. Barcelona, Spain.2004.
[44]Yiming, L., Shaoqi, Z., Fuzhen, L. and Yixiao, L. Utilization of municipal sewage sludge as additives for the production of eco-cement. Journal of Hazardous Material. Vol. 213, 2012, pp 457-465.
[45]Valls, S.. Yague, A., Vazquez, E. and Albareda, F. Durability of concrete with addition of dry sludge form waste water treatment plants. Journal of Cement Concrete. Vol. 35, 2005, pp 1064-1073
[46]Kartini, K., Dahlia Lema, A.M., Quraisyah, S.D., A, A., Anthony, A.D., Nuraini, T. and Siti, R.R. Incinerated domestic waste sludge powder as sustainable replacement material for concrete. Journal of Science and Technology. Vol. 23, 2015, pp 193-205.
[47]British Standard Institution BS EN 12390-3:2000. Testing Hardened Concrete. Compressive Strength of Test Specimen.
[48]British Standard Institution BS EN 12390-8:2000. Testing Hardened Concrete. Depth of Water Under Pressure.
[49]British Standard Institution BS 1881-122:2011. Testing Concrete-Method for Determination of Water Absorption, London.
[50]Ghusain, I. Al. and Terro, M. J. Use of treated wastewater for concrete mixing in Kuwait. Kuwait Journal of Engineering and Science. Vol. 30, 2003, pp 213-228.
[51]Roccaro, P., Franco, A., Contrafatto, L. and Vagliasindi, F.G.A. Use sludge from water and wastewater treatment plants in the production of concrete: an effective end-of-waste alternative. Proceeding of the 14th International Conference on Environmental Science and Technology. 2015.
[52]Suzuki, S., Tanaka, M. and Kanekom T. Glass ceramic from sewage sludge ash. Journal of Material Science. Vol. 32, 2997, pp 1775-1779.
[53]Ferreira, C., Riberiro, A. and Ottosen, L. Possible applications for municipal solid waste fly ash. Journal of Hazardous Material. Vol. 96, 2003. pp 201-216.
[54]Montero, M.A., Jordan, M.M., Hernandez-Crespo, M.S. and Sanfeliu, T. The use of sewage sludge and marble residues in the manufacture of ceramic tile bodies. Journal of Applied Clay Science. Vol. 46, 2009, pp404-408.
[55]Joan, A.C. and Cecilia, S. Valorization of pellets from Municipal WWTP sludge in lightweight clay ceramics. Journal of Waste Management. Vol. 31, 2011, pp 1372-1380.
[56]Martinez-Garcia, C., Eliche-Quesada, D., Perez-Villarejo, L., Iglesias-Godino, F.J. and Corpas-Iglesias, F.A. Sludge valorization from wastewater treatment plant to its application on the ceramic industry. Journal of Environmental Engineering. Vol. 95, 2012, pp 5345-5348.
[57]Zhikun, Z., Zhang, L., Yin, Y.L., Liang, X. and Aimin, L. The recycling of incinerated sewage sludge ash as a raw material for Cao-Al2O3-SiO2-P2O5 glass-ceramic production. Environmental Technology. Vol. 36, No. 9, 2015, pp 1098-1103.
[58]ASTM C618, Standard specification of coal fly ash and raw or calcined natural pozzolans for use in concrete. 2008.
[59]EN 196-5. Pozzolanicity test for pozzolanic cement.
[60]ASTM C311, Standard test methods for sampling and testing fly ash or natural pozzolans for use in concrete. 2007.
[61]Danatello, S., Freeman-Pask, A., Tyrer, M. and Chesseman, C.R. Effect of milling and acid washing on the pozzolanic activity of incinerator sewage sludge ash. Chemical Concrete Compositions. Vol. 32, 2010, pp 54-56.
[62]Tantawy, M.A., El-Roudi, A.M, Elham, M.A. and Abdelzher, M.A. Evaluation of the pozzolanic activity of sewage sludge ash. International Scholarly Research Network ISRN Chemical Engineering. 2102: 8 pages.
[63]Drazen, V., Domagoj, N. and Nina, S. Reuse of sewage sludge- problems and possibilities. 2015.
[64]Badr, E.D.E.H., Hegazy, A. F. and Ahmed, M.H. Brick manufacturing from water treatment sludge and rice husk ash. Australian Journal of Basic and Applied Science. Vol. 6, 2012, pp 453-461.
[65]Jamshidi, A., Jamshidi, M., Mehrdadi, N., Shasavandi, A. and Pacheco-Torgol, F. Mechanical performance of concrete with partial replacement by sewage sludge ash. VI International Materials Symposium. 2011.

Tan Yeong Yu Current position is master student at University Malaysia Pahang. Bachelor in Civil Engineering (HONS.) at University Malaysia Pahang.

Doh Shu Ing Senior lecturer at University Malaysia Pahang. PhD at University Malaysia Sabah, Major in materials and structural.

Chin Siew Choo Senior lecturer at University Malaysia Pahang. PhD at Universiti Teknologi PETRONAS, Major in materials and structural.

Yap Hiew Thong Current position is master student at University Malaysia Pahang. Bachelor in Civil Engineering (HONS.) at University Malaysia Pahang.