The industrial research on the co-disposal of municipal sludge using new dry process cement kiln

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Keywords: Sludge; Cement kiln; co-disposal; Industrial research

Abstract. Co-disposal of sewage sludge in cement kiln is an economic and feasible method of resource utilization. The industrial test of co-disposal sludge was carried out in Beijing Taihangqianjing cement limited company. The semi drying sludge as a raw material was transported to the decomposition furnace for combustion by bucket elevator. The physical properties and mineral composition of the cement clinkers produced with and without sludge were compared and analyzed. The result showed that the chemical composition and properties of the clinker were similar to the untreated sludge in the process of co-disposal sludge by cement kiln. There was no obvious change in the specific surface and setting time whether co-disposal sludge or not ($p>0.05$). The fineness of clinker was reduced when co-disposal sludge to a certain extent, and the standard consistency water demand ratio was slightly lower. The 28d compressive strength and breaking strength were increased evidently. It can be seen that the dry sludge as a substitute for cement kiln is feasible.

Introduction

With the rapid development of China's socio-economic, urbanization and industrialization, urban sewage production increased year by year. As a by-product of urban sewage treatment, sludge production will be rapid growth, the harmless and resources treatment of sludge is imminent [1-3].

It is a good way to use the dry cement kiln to treat municipal sewage sludge[4,5]. The main chemical components of the sludge include SiO_2, Fe_2O_3, and $A1_2O_3$, it is very similar to the silica raw material that contained in the cement raw materials. In theory, the sludge can be used to substitute for the silica raw materials during cement production [6]. The technology of co-disposal sludge using cement kiln has been developed rapidly in Japan, Spain, Italy, Germany, France and so on, and has become an important part of the sludge final disposal and resource [7].

In China, the research on the co-disposal sludge by cement kiln is relatively late. Although China has made some progress in the research of this technology, the experimental research of industrialization is relatively small. In this study, the feasibility of using sludge in the production of ecological cement was studied through the experimental research on the industrialization of cement kiln co-treatment sludge.

Test site and method

Sludge disposal process. The industrial test of co-disposal sludge by Beijing Taihangqianjing

cement limited company was carried out in full in 2015. The daily output of cement clinker is 3200 tons of the cement company. The amount of combustion sludge (moisture content is 60%) is 36 tons per day. The sludge (moisture content of 60%) was transported to cement plant from water treatment plant. Firstly, the sludge was placed in the sludge storage warehouse, then the sludge transported to the cache warehouse and ready for weighing. After weighing the sludge was transported to the decomposition furnace for combustion by bucket elevator. The performance of sludge samples and cement clinker were analyzed in sludge combustion process by cement kiln.

Analysis method. The chemical composition of sludge was analyzed reference to GB/T176-2008 "cement chemical analysis method", the chemical composition of sludge ash and clinker were determined using fluorescence analysis. The specific surface area was determined according to GB/T 8074, fineness test according to GB/T 1345.The test of water quantity, setting time and stability of cement standard consistency was carried out according to GB/T 1346, and the strength was analyzed by T/GB 17671.

Results and discussion

Characteristics of sludge. The sludge come from Beijing Xiaohongmen wastewater treatment plant, 2 sludge samples were collected and analyzed. The proximate analysis of sludge samples were shown in Table.1.The moisture content of sludge is about 61%, the ash content is about 51%, the heat value of the sludge is about 9 Mj/kg. The chemical composition and content of the material determines the use of the substance. Table.2 shows the proximate analysis of sludge samples, the main components in the ash of the 2 sludge samples all are CaO, Fe_2O_3, SiO_2, and Al_2O_3, and it is similar to the raw materials for cement production. In that sense, sludge can be used as an alternative raw material for cement plant. Sludge also contains a high P_2O_5, SO_3, K_2O and MgO, etc. to the disadvantage of the composition of the cement kiln, which will affect the normal operation of cement kiln and cement quality. For co-disposal sludge by cement kiln, these adverse elements must be control, or to take the appropriate measures to reduce emissions.

Table.1 Proximate analysis of sludge samples

Number	Moisture content [%]	Ash content [%]	Volatile matter [%]	Heat value [Mj/kg]
Samples1	60	52.5	49.6	9.101
Samples2	62	49.9	49.6	9.005

Table.2 Composition analysis of sludge ash[%]

Number	CaO	Fe_2O_3	SiO_2	SO_3	P_2O_5	Al_2O_3	MgO	Na_2O
Samples1	17.124	9.305	8.822	4.202	5.053	4.153	2.270	0.282
Samples2	15.381	10.104	8.632	4.348	3.864	3.481	2.013	0.359
Number	K_2O	Cl	TiO_2	CeO_2	ZnO	MnO	Cr_2O_3	PtO_2
Sample 1	0.325	0.466	0.129	0.000	0.069	0.035	0.000	0.000
Sample 2	0.350	0.303	0.134	0.108	0.099	0.037	0.030	0.021
Number	SrO	CuO	H	BaO	ZrO_2	PbO		
Sample 1	0.021	0.000	0.004	0.140	0.000	0.000		
Sample 2	0.017	0.016	0.005	0.000	0.000	0.000		

Influence of combustion sludge on cement clinker. Table.3 shows the composition of cement clinkers with and without sludge. From the composition of the clinker, the chemical composition and properties of the clinker were similar to the untreated sludge in the process of co-disposal sludge by cement kiln. Statistical analysis shows that the effect of co-disposal sludge on the

composition of clinker was very small (p>0.05).

Table.3 Composition analysis of cement clinkers with and without sludge[%]

Item	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	SO_3	KH	n	p
With sludge	20.00	5.28	3.46	60.61	4.35	0.08	0.64	0.91	2.35	1.58
Without sludge	21.10	4.99	3.52	63.60	4.20	0.07	0.68	0.92	2.48	1.42

Physical properties of cement clinker were shown in Table.4. The percentage of the sieve and the specific surface area are usually used to explain the fineness of cement. There was no obvious change in the specific surface when co-disposal sludge or not (p>0.05). The fineness of clinker was reduced when co-disposal sludge to a certain extent. There was no significant change in the setting time, whether the initial setting time and final setting time, while the standard consistency water demand ratio was slightly lower.

Table.4 Physical properties of cement clinkers with and without sludge

Item	Specific surface [$m^2.kg^{-1}$]	Fineness [%]	Water demand ratio [%]	Initial setting time[min]	Final setting time[min]
With sludge	349	1.5	23.8	98	151
Without sludge	349	2.0	24.0	95	150
Standard	⩾300	⩽10		⩾45	⩽600

The breaking strength and compressive strength of cement clinker before and after the addition of sludge are shown in Table.5. It can be seen that the 3 days of breaking strength and the compressive strength of cement clinker were not significantly changed before and after the addition of sludge, while 28 days of the breaking strength and the compressive strength were significantly improved. From the test results of flexural and compressive strength, there is no obvious change in the early strength of cement clinker, but the late strength of the cement clinker is obviously improved. This may be due to the incorporation of sludge into the crystal form of the clinker in the occurrence of changes, which affect the cement hydration time.

Tab.5 Strength of cement clinkers with and without sludge[MPa]

Item	Breaking strength		Compressive strength	
	3d	28d	3d	28d
With sludge	6.61	8.48	33.98	52.01
Without sludge	6.59	8.65	33.79	53.06

Conclusion

(1) The main components in the sludge ash are very similar to the raw materials for cement production. In that sense, sludge can be used as an alternative raw material for cement plant. However, the sludge also contains a number of components that are not conducive to the production of cement, these adverse elements must be control or to take the appropriate measures to reduce emissions.

(2) The chemical composition and properties of the clinker were similar to the untreated sludge in the process of co-disposal sludge by cement kiln. There was no obvious change in the specific surface and setting time whether co-disposal sludge or not ($p>0.05$). The fineness of clinker was reduced when co-disposal sludge to a certain extent, and the standard consistency water demand ratio was slightly lower.

(3) The 3 days of breaking strength and the compressive strength of cement clinker were not significantly changed before and after the addition of sludge, while 28 days of the breaking strength and the compressive strength were significantly improved.

Acknowledgements

This study was financially supported by the key science and technology project of BBMG(B0018), and by the country “12th Five-Year Plan” to support science and technology projects (2012BAC15B04), the work also funded by the national "863 Plan" project(2013AA031602).

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