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硕 士 学 位 论 文

生活垃圾焚烧炉渣作为混凝土细骨料的
可行性研究

The Feasibility Study on the Municipal Solid Waste
Incineration Slag as Fine Aggregate of Concrete

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摘 要

随着城镇化的快速推进和人民生产、生活的发展,大量增加的生活垃圾已成为全国一个比较严重的社会问题。发达国家的发展历程表明,通过焚烧可使垃圾减量 80%~85%,减容约 90%,但仍将残留总重约 10%~20%的焚烧炉渣,大部分炉渣进入填埋场进行填埋处置,这将显著增加城市周边填埋库容的压力,占用大量的土地。

与此同时,大规模的城镇化和基础设施建设对于混凝土的需求量稳定增长,混凝土用砂数量巨大,加上砂浆和其他用途,估计每年全国需要 30 亿吨以上建设用砂。随着对砂子的不断开采,全国天然河砂资源趋于枯竭。福州、厦门、漳州等沿海地区出现了天然河(江)砂资源急剧减少、质量下降、限采或禁采的情况,混凝土用砂供需矛盾尤为突出。河砂的价格越来越高,用砂高峰时甚至无砂可用,成为制约混凝土行业发展的瓶颈。混凝土生产企业不得不采用机制砂、混合砂以及经淡化处理的海砂。机制砂配制的混凝土工作性不易控制,海砂若淡化处理不当将导致混凝土中的钢筋锈蚀,构件膨胀开裂,从而给建设工程带来严重隐患。

在我国,垃圾焚烧及焚烧炉渣利用本身就是新事物,焚烧炉渣在混凝土中的应用更是新课题,近二十年才引起专家、学者的关注。目前国内外的研究多集中在将焚烧炉渣作为混凝土粗骨料或水泥的替代材料,但是作为细骨料的研究少见,而炉渣与混凝土细骨料的物理性质和化学性质有一定的相似性。因此,本文以漳州龙海生活垃圾焚烧炉渣为研究对象,研究、分析焚烧炉渣用作混凝土细骨料替代材料的可行性,以达到利废环保、节约资源的目的。

本文主要工作内容和研究成果如下:

(1) 采用人工筛选与机械筛选相结合的方法,分析生活垃圾焚烧炉渣的物质组成,并且采用物理和化学方法测试分析了焚烧炉渣的理化性质。研究表明:焚烧炉渣与天然河砂具有一定的相似性,且不存在放射性危害和重金属毒性危害,但在部分指标上和河砂有较大的出入,有待预处理修正。

(2) 以生活垃圾焚烧炉渣在混凝土中的资源化利用为出发点,研究、制定特殊的生活垃圾焚烧炉渣预处理方法。研究表明:经过预处理后,焚烧炉渣中的氯盐、硫酸盐、轻物质等有害物质急剧减少,颗粒级配良好,细度模数显著增大,

整体性能得到较大改善。

(3) 开展了利用生活垃圾焚烧炉渣制备炉渣混合砂的理论研究和试验研究。在建立混凝土细骨料自由堆积模型的基础上,选取粒度适宜的天然河砂与焚烧炉渣复配,通过大量的试验研究得到二者的最佳配比,研制出新型混凝土用人工砂—炉渣混合砂;依据《建设用砂》标准,测试、分析炉渣混合砂的物理性质和化学性质,为炉渣混合砂在混凝土中应用提供了理论依据。在此基础上,进一步开展了炉渣混合砂的制备工艺及产业化研究。

(4) 利用所研发的炉渣混合砂配制 C30 级混凝土,测试混凝土的工作性能和力学性能,从技术、经济、环保等方面分析炉渣混合砂在混凝土中应用的可行性。结果表明:课题组自主研发的炉渣混合砂能够配制出合格的混凝土。技术层面,利用炉渣混合砂配制的 C30 混凝土满足工作性和力学性能设计要求;造价层面,每立方米 C30 级混凝土的配制成本可降低 8.2 元;环保层面,炉渣混合砂的使用不仅解决生活垃圾焚烧炉渣“围城”,同时解决当下河砂资源紧缺的现状,意义深远。因此,生活垃圾焚烧炉渣作为混凝土细骨料具有可行性。

关键词: 生活垃圾焚烧炉渣; 预处理; 复配; 混凝土细骨料; 炉渣混合砂

Abstract

With the rapid development of urbanization and the development of people's production and life, a large increase of domestic waste has become a more serious social problem. The development course of developed countries show that by burning the domestic waste reduction from 80% to 85%, volume reduction of about 90%, but still remaining about 10% to 20% of the incineration slag, and most of the slag is poured into the landfill site for landfill disposal, which will significantly increase the pressure of urban landfill capacity, occupy a lot of land.

At the same time, large-scale urbanization and infrastructure construction for the concrete demand to stabilize growth, concrete with a huge amount of sand, plus mortar and other purposes, the country needs an estimated three thousand million tons per year on the construction of sand. With the continuous exploitation of sand, the natural river sand resources become depleted. The natural river sand resources in Fuzhou, Xiamen, Zhangzhou and other coastal regions decreased sharply, the decline in the quality and limitation or ban case, concrete sand supply and demand contradiction is particularly prominent. River sand prices are getting higher and higher, with the peak of sand and even without sand available, which has become a bottleneck in restricting the development of the concrete industry. Concrete production enterprises have to adopt mechanism sand、mixed sand and sea sand after desalination process. Preparation of mechanism sand concrete workability is not easy to control, meanwhile if the desalination about sea sand handle improperly will lead to the corrosion of rebar in concrete, component expansion cracks, thus bring serious hidden danger to engineering construction.

In our country, waste incineration and the use of incineration slag is a new thing, the application of incineration slag in concrete is a new topic, which has attracted the attention of experts and scholars in recent twenty years. Currently researches are more concentrated in the incinerator slag as coarse aggregate of concrete or cement replacement materials, but as the fine aggregate of rare. In fact, the physical and chemical properties of the slag and fine aggregate in concrete have certain similarity.

Therefore, to protect the environment and save the resource, this paper takes the Longhai Zhangzhou municipal solid waste incineration slag as research object, analyzes the feasibility of using municipal solid waste incineration slag as a substitute material of concrete fine aggregate. The main contents and results are as follows:

(1) The material composition of waste incineration slag was analyzed by the method of artificial selection and mechanical screening, and the physical and chemical properties of the slag were tested by physical and chemical methods. The research shows that incineration slag and natural river sand has a certain similarity, and there is no radioactive hazard and heavy metal toxicity hazard. But it is quite different from the river sand in some indexes, and needs to be pretreated amended.

(2) Based on the resource utilization of the waste incineration slag in concrete, research and formulate a special waste incineration slag pretreatment method. The research shows that the harmful substances such as chlorine salt, sulfate and light matter have been reduced sharply, the particle size distribution is good, the fineness modulus has been significantly increased, and the overall performance has been greatly improved.

(3) Experimental study on the preparation of slag mixed sand by using municipal solid waste incineration furnace slag is carried out. On the basis of the establishment of concrete fine aggregate free packing model, select the appropriate size of the natural river sand, find the best compound proportion of slag and river sand through a large number of experimental study, develop a new artificial sand for concrete—slag mixed sand; Based on 《Building Sand》 standard, test and analysis physical and chemical properties of slag mixed sand, provides the theory basis for the application of slag mixed sand in concrete, meanwhile make a preliminary study on the industrialization of slag mixed sand.

(4) Preparation of C30 grade concrete by using the developed slag mixed sand, test the working performance and mechanical properties of concrete, analyze the feasibility of the application of slag mixed sand in concrete from the aspects of technology, economy, environmental protection and so on. The results show that: The slag mixed sand which were independently developed by research group can produce

qualified concrete; Technical level, the preparation of C30 grade concrete by using slag mixed sand meet the workability and mechanical properties of design requirements; Cost level, per cubic meter of C30 grade concrete preparation cost can reduce 8.2yuan; Environmental protection level, the use of slag mixed sand not only solve garbage incineration furnace slag, but solve the current river sand resources shortage situation. Therefore, the waste incineration slag as a concrete fine aggregate is feasible.

Key words: municipal solid waste incineration slag; pretreatment; compound; concrete fine aggregate; slag mixed sand

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第一章 绪论

1.1 研究背景

1.1.1 生活垃圾概述

进入 21 世纪以后，人类的城市化进程日渐显著，尤其是近十年，随着全国房价的不断飙升，城市包围农村的走势越发明朗，城市的数量和规模都在不断攀升。城市的发展与社会的进步提高了人们的生活质量，但也造成了环境污染的不断加剧，大量的生活垃圾就是人们老生常谈的一个话题。据统计，垃圾产量最多的国家是美国，年产量超过 $2.5 \times 10^8 \text{ t}$ ，德国与日本垃圾产量同样居高不下^[1]。发达国家需要考虑生活垃圾问题，发展中国家同样要应对生活垃圾带来的困扰，2015 年的印度瓦拉纳西，大量垃圾污染恒河支流，并流入恒河，印度“圣河”演变成一条垃圾河，如图 1.1 所示。同样，菲律宾曾因为垃圾山的倒塌致使人员伤亡事故^[2]，如图 1.2 所示。



图 1.1 印度“圣河”



图 1.2 著名菲律宾垃圾山

相比之下，国内生活垃圾产量也不容小视，中国是个人口大国，垃圾产量自然居高不下，总结近几年城市生活垃圾处理量^[3-7]，如图 1.3 所示。

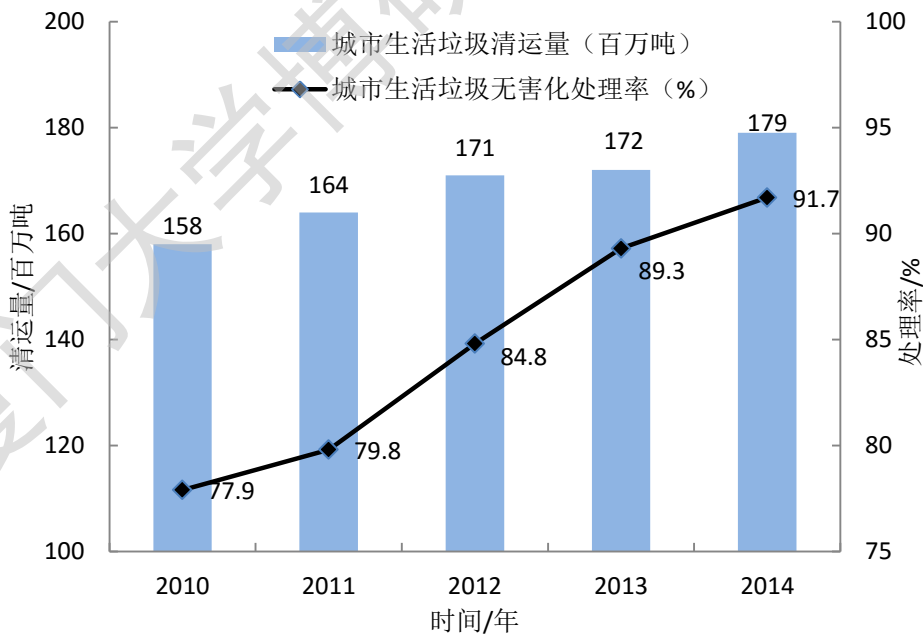


图 1.3 城市生活垃圾清运量和无害化处理率

过去由于国家技术发展水平落后，城市生活垃圾基本上不做任何处理，主要处理方式就是在郊外、山沟、荒地进行堆放，这无疑会造成“垃圾围城”。现阶段

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