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Environmental performance, mechanical and microstructure analysis of non-fired bricks containing water-based drilling cuttings of shale gas

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HIGHLIGHTS

- WDC have certain pozzolanic characteristic and a significant impact on the durability and strength of non-fired bricks.
- The appropriate preparation conditions of the MU10 grade bricks from water-based drilling cuttings were achieved.
- Different hydration products of water-based drilling cuttings non-fired bricks are detected by testing methods.
- The environmental performance of WDC bricks was very well.

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ABSTRACT

The exploration and development of shale gas technology provide a way to utilize clean fuels with high efficiency and minimum environmental impact. However, the accumulation of water-based drilling cuttings (WDC) from oil and gas field development is causing serious waste of land resources and environmental safety problems. This work presents an experimental study on the feasibility of recycling original WDC as replacements for fine aggregates and as part of cementitious materials for the manufacture of non-fired bricks. Mechanical and physical properties, detailed environmental performance, and microstructure analysis were carried out. Meanwhile, the original hydrated products and hydration process of WDC brick were evaluated with, FT-IR (Fourier transform infrared), XRD (X-ray diffraction), SEM (scanning electron microscopy) and EDX (energy-dispersive X-ray spectroscopy). The outcomes indicated that WDC have certain pozzolanic characteristic and a significant impact on the durability and strength of non-fired bricks. The best properties achieved with the help of 50% WDC which meet grade M10 according to a Chinese standard (GB/T2542-2012). Environmental performance tests provides that the WDC used as the raw material for non-fired bricks, and from the technical point of view, does not have environmental pollution.

1. Introduction

With China's rapid growth in the economy, the energy demands have constantly been rising and shale gas as the new alternative energy resource, it has become a major inspiration for economic growth in China. During the exploration and mining of shale gas, a straight hole of water-based drilling fluid is used, it then circulates the ground which comprises of water-based mud and water-based cuttings. The water-based cuttings and drilling fluid pre-processes are always done through an oscillating screen system, to generate the water-based drilling cuttings. About 1000 m^3 of water-based cuttings could be discovered in one well. To ensure safe discharging of WDC, Considering the fact that this type of solid wastes contain organic pollutants andneeds to be done in terms of the security handling, pressure filtration method is also employed in the pre-prosesses of the WDC. After that the water content of the WDC is kept within 15% to ensure that it could be solidified fast.

To convert WDC into solids, a certain degree of strength hardening agents like cement is added. By doing so, the solving of the contamination of WDC can be done within a short period

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of time. Basically, by the process of solidification [1–4], the absolute dominant contaminants found in the WDC get blended in the solidified blocks. However, it is clear that this curing process only blended the contaminants in the solidified blocks instead of overcoming them. So, when the solidified blocks are buried for long time, it will undergo a series of changes because of the effects of chemical, biological and physical processes yielding a secondary pollutant [5–7]. From Fig. 1 it can be seen that the process of solidifying WDC is tedious. In addition to, some other problems appear simultaneously, such as large area occupation, high construction and maintenance cost. Therefore, a safe and environmental-friendly way of disposing of cuttings during the development and exploration of shale gas is needed with urgency.

According to the results of researches [8–11] concerned in oil and gas industry and the analysises of the mineral composition, and chemical composition, particle size distribution, and WDC's pozzolanic activity index. The present study investigates the potential use of WDC of make bricks by partial replacement of fine aggregates and cementitious materials. The innovation of this paper is not only developed a new-style and cost savings material from WDC, but also eliminate the potential environmental safety hazard. To achieve the goal mentioned above, mechanical and physical properties, detailed environmental performance, and microstructure analysis were carried out. Meanwhile, modern analytical methods have been used to investigate the early hydration process and hydrated products of WDC bricks. This study can provides an effective method for the WDCs' environmental and safe dispose and substance recycling, and plays an important role in standard guidance on drillings resource usage.

2. Preparation of WDC brick

2.1. Treatment processes of water-based drillings

During shale gas mining and development process, around 1000 m^3 of water-based drillings would be generated as a harmful by-product which contains organic pollutants formed in a well. This solid has to be pre-processed before they are disposed to ensure that they are safe. Fig. 1 represent the drawing of the treatment process and a comprehensive WDC utilization. It is shown clearly the pressure filtration method is the final technique that can be used to dispose of water-based drillings. Since the water content of the residue is maintained within 15%, resource utilization becomes easy.

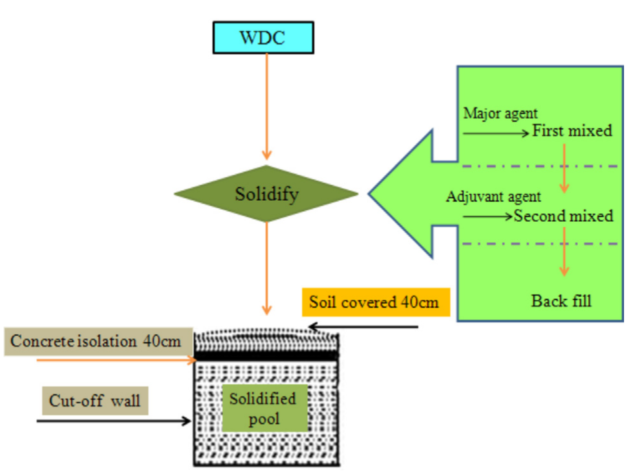

Fig. 1. Solidify processes of WDC.

2.2. Mixing proportions and test methods

2.2.1. Materials preparation

The Sichuan cement co, LTD's Commercial ordinary Portland cement 42.5 (P.O. 42.5) was used in this study. WDC was provided bythe shale gas exploration and development company Chongqing filing, SINOPEC (China). Fly ash was sourced from a power plant in Jiangyou city (Sichuan province). For mixing and curing processes portable water was used. Table 2. Shows their chemical compositions.

The fine aggregates (0.5–1 mm) were manufactured sand with a fineness modulus of 3.16. The mixing composition by weight of the mixture and the major parameters are given in Table 1.

2.2.2. Mixing proportions

Based on the results of preliminary experiments, the product performance is optimized obviously by adding WDC and regulating amount of water consumption, which can improved the product performance obviously. The mixing proportions of WDC brick are presented in Table 1. In total, 5 brick mixes were made, of which the first batch was the control group without any WDC. Another 4 batches were made with WDC by replacing manufactured fine aggregates in ratios of 30%, 40%, 50% and 60% of total weight.

As showed in Table 1, 0.25 kg of binder (02 kg of cement and 0.05 kg of fly-ash) and a slight variation water-binder ratio of 0.19/0.19/0.20/0.21/0.22 were used in all brick productions. The amount of WDC added was kept constant at 0.375/0.5/0.625/0.75 respectively, of the each manufactured sand weight in every mixture.

2.2.3. Preparation of the bricks

The cement, WDC and fineaggregates were mixed uniformly with a mixer for about 1 min, and then add the water and slowly mix for about one minute. And lastly, mix all the materials for another 2 min.

The size of brick specimens was 240 mm × 115 mm × 53 mm cubes casted by steel molds, and then the specimens were compacted by a pressure test machine with the pressure of 3 MPa. All bricks were placed for 24 h on indoor conditions , then demold and moved into an ideal curing room with a 95% relative humidity temperature of (20 ± 1) °C in defined period.

2.3. Test methods

A battery of 20 mm × 20 mm × 20 mm paste were prepared corresponding to the water-binder ratios listed in Table 1. And all samples were removed from the steel molds after 24 h, then monitored in a curing box with 95% relative humidity and temperature under (20 ± 1) °C for 28 days. Crush the samples and fine ground until it can through the 200 mesh sieves, and the powder were vacuum dried and analyzed by FT-IR, XRD, and SEM.

2.3.1. Strength activity index (SAI)

Mortar specimens of 40 × 40 × 160 mm^3 were prepared and its compressive strength were tested according to ISO-679:1989 which maintained in binder to water ratio of 2:1. Using ordinary Portland cement as control group, and the composition of experimental group is 70% PC and 30% WDC. From complementary perspective, a pozzolan sample was prepared by utilizing 30% w/w of WDC as PC's replacement. All mortar samples demould after 24 h, and then moved into ideal curing room which is in 95% relative humidity and temperature of (20 ± 1) °C in 28 days. Three specimens were tested at each age to determine the compressive strength. The outcomes discussed in this study are the average results of the mechanical property. The test of compressive