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Sustainable cement slurry using rice husk ash for high temperature oil well

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ABSTRACT

In oil well cementing where high temperature are involved, a silica source is add to the cement composition to inhibit cement sheath compressive strength retrogression. The mechanical properties of cement used in oil wells may benefit from the incorporation of rice husk ash (RHA) due to its high silica content. RHA has also become attractive as cement additive owing to its low cost and renewability. The aim of the present study was to develop a cement slurry for high-temperature oil well using RHA as anti strength retrogression additive. A typical G cement slurry was prepared with 40% of RHA and submitted to curing cycles of 7–28 days to evaluate the influence of the RHA at both the bottom hole static temperature (BHST) and 300 °C. The results showed that the addition of RHA increased by 30.55% the compressive strength after curing for 28 days at BHST conditions and by 11.18% at 300 °C. XRD analysis of high temperature cycles showed the presence of xenotlite and tobermorite, which are crystalline phases responsible to maintain the cement compressive strength. The RHA has been shown to be a sustainable alternative to commercial silica flour. In addition, the present study envisages the RHA disposal to be considerably reduced by its application in the petroleum industry.

1. Introduction

The cementing job is one of the most important activities in oil well construction that occur after the drilling phase by positioning a cement slurry in the annular between the casing and the rock formation (Nelson and Guillot, 2006). One important objective of primary cementing is to promote zonal isolation between rock layers to keep undesirable fluids away from hydrocarbon reservoirs. The most used binding material in oil well cementing are the Class G or H Portland cement specified by American Petroleum Institute (API). Under high temperature conditions (150–300 °C), usually reached in a oil well submitted to steam injection for oil recovery (Fig. 1), the cementitious material must present specific physical and chemical properties in order to maintain the hydraulic seal of the wellbore (Luke et al., 1981).

At high temperatures occurs the cement sheath retrogression: phenomenon that decreases the compressive strength and increases the cement matrix permeability due to the metamorphism of C–S–H phase, that becomes alpha dicalcium silicate hydrate (α-C_2SH), a highly crystalline and denser phase (Luke, 2004; Nelson et al., 1981). Cement sheath retrogression can be prevented by reducing the Ca/Si ratio on the cement slurry formulation. In order to achieve that, silica flour must be added with concentrations ranging from 35 to 40% BWOC (By Weight of Cement). When Ca/Si ratio is about 1.0, crystalline phases known as tobermorite ($C_5S_6H_5$), xenotlite (C_6S_6H) and truscottite ($C_7S_{12}H_3$) are formed to preserve the compressive strength and permeability of the cement (Nelson et al., 1981; Nelson and Guillot, 2006).

The partial replacement of cement for waste materials has been reported in several studies, being majority of them focused on the civil construction industry, since cement accounts for 8% of greenhouse gas emissions (Mikulčić et al., 2016; Mutuk and Mesci, 2014; Teh et al., 2017). The management and use of solid waste has been researched as a way to minimize environmental impacts.

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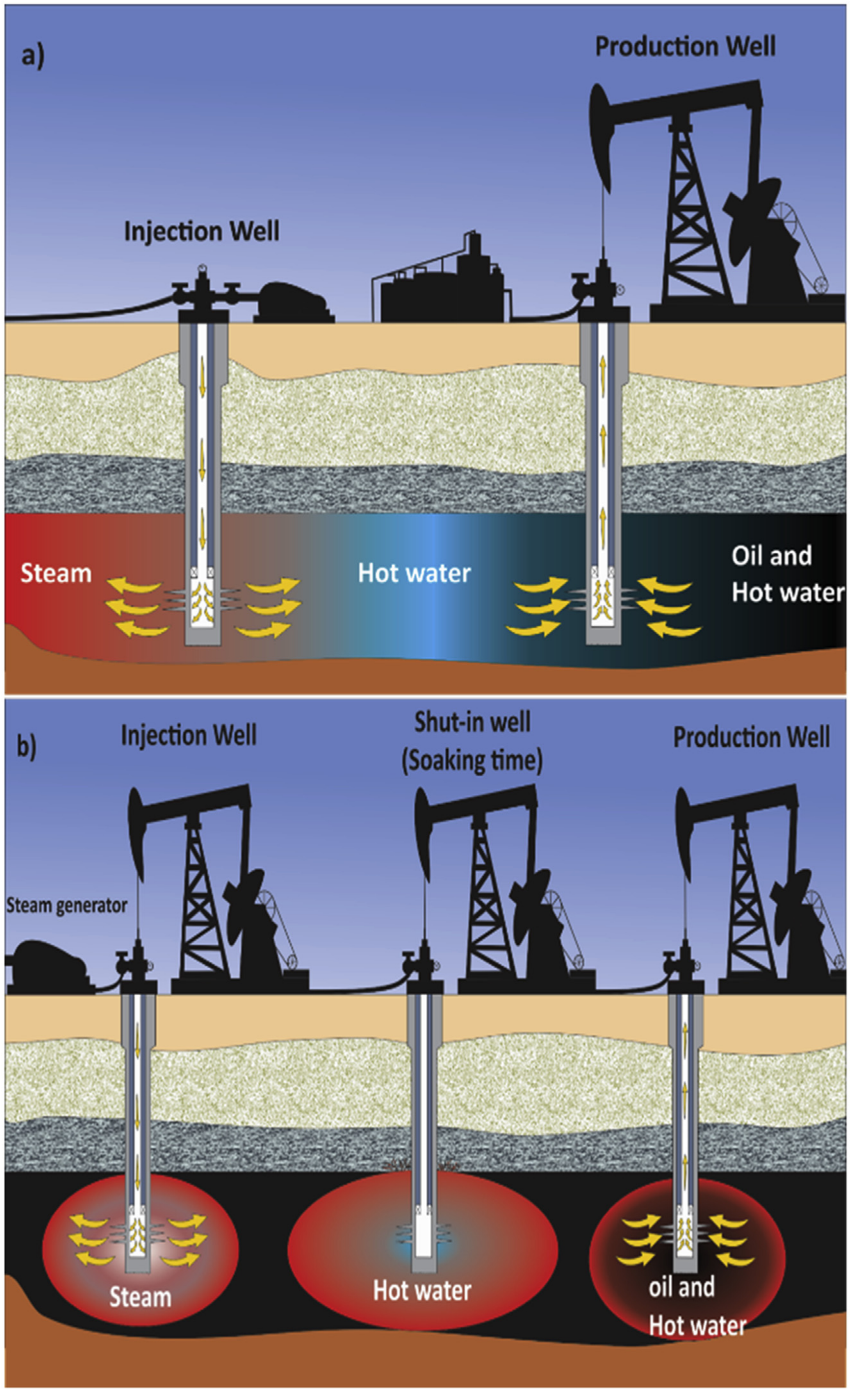

Fig. 1. Steam injection scheme: (a) continuous steam injection heats up the reservoir and its fluids pushing the oil towards the producing wells and (b) cyclic steam injection of steam, the well remains closed in order to occur energy dissipation (soaking period), and after some days it is opened producing heated oil with lower viscosity.

Wastes as phosphogypsum, construction demolition waste, corncob ash, wood waste and sugarcane biomass waste have been used in concretes and mortars for partial replacement of cement (Anjos et al., 2013; Chen et al., 2018; Emeritus, 1998; Memon and Khan, 2018; Usman et al., 2018). Bie et al. (2015) showed that the production of rice husk ash (RHA) from calcination in a controlled environment at 600 °C produces a pozzolanic material with better quality and greater reactivity. The RHA is considered a pozzolanic material, due to its large silica content (Soares et al., 2015). The pozzolanic reaction occurs between the calcium hydroxide (CH), one of the cement hydration products, and the acid oxides present in pozzolan, generating as main product the calcium silicate hydrate (C—S—H) (Malhotra and Mehta, 1996).

In addition to its abundance and renewable origin, there is noble compounds in the rice waste, such as the silica in rice husk ash (RHA), that can bring huge benefits to the industrial processes of concrete, rubber, ceramic production, insulator, adsorbents among others (Prasara-A and Gheewala, 2017). According to FAO (2017), the world rice production in 2017 was estimated at 756.7 million tons (502.2 million tons, milled basis). The beneficial effect of RHA