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Case study

Benefits of using mineral additives, as components of the modern oil-well cement

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ABSTRACT

In this study the Influence of fine mineral additives such as zeolite tuff, metakaolin, microspheres and fly ash on the properties of light-weight oil-well cement was investigated. Strength, physical and performance requirements of light-weight oil-well cements were determined. The results have shown that the most effective facilitating additive which gives the lowest density is the microsphere. However, at raised pressures, it has been revealed that walls of the grains of the microspheres do not withstand a pressure of more than 20 MPa, and thus they will be destroyed leading to an increase in the density of the slurry and significantly limits the permissible depth for using this composition. On the other hand, it was found that using zeolite in combination with metakaolin improves the physico-mechanical properties of the oil-well cement stone.

1. Introduction

The modern techno-economic challenges regarding the development of the world economy require the activation of works to search for, investigate and develop oil and gas fields. The development of wells is a time-consuming process, which consists of a large number of operations using special equipment, and is accompanied by multi-million expenses.

As the depth of drilling increases, the well temperature also increases. This causes a number of problems on the stages of construction and subsequent operation of the wells. Oil well cement (OWC) is specially manufactured for use while drilling oil wells to fill the space between the steel castings and the wall of the well. In order to give the slurry made from it sufficient time to reach the high depths of oil wells, the (OWC) usually has a controlled setting under high temperature and pressure conditions. However, once setting takes place it develops strength rapidly and remains stable at high temperatures. One of the important requirements before introducing wells into operation is the strengthening of the casing columns and insulation of layers by injecting grouting materials [1]. For these wells, lightweight oil-well cements are used, which are made by replacing part of the clinker component with mineral additives with low density (zeolite tuffs, microspheres, fly ash), as well as with a significant increase in the water-cement ratio [2]

The fly ash used as a mineral additive in cementitious products can be separated from the flue gas of a power station burning pulverized coal. The chemical composition of the resulted fly ash depends on the minerals associated with the coal [3]. In this study, metakaolin which is a high reactivity metastable phase originated from the calcination of the mineral kaolinite at 700–800 °C was used as a pozzolanic material [4]. However, there are also many researches who investigated the possibility of using other sources of silica for cement-based products such as rice husk ash [5], sugar cane biomass ash [6], natural zeolite tuffs [7]. The advantage of using zeolite tuff in such systems is its high-porous structure, which allows to absorb enough water without causing separation of the mixture with height in the beyond-column space.

A number of studies have investigated the use of different additives on the mechanical properties of oil well cement [2,8]. However, requirements for modern oil-well materials include the development of new lightweight oil well cement [9]. The use of

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Table 1
Chemical properties of binders.

Oxide composition % by mass	cement	zeolite	Metakaolin	Fly ash	Microspheres
CaO	62.95	1.89	3.87	1.22	4.5
SiO_2	20.56	68.45	73.20	61.64	62.98
Al_2O_3	6.76	14.01	18.31	27.9	22.65
Fe_2O_3	3.89	1.22	0.84	5.7	0.47
MgO	2.23	1.15	0.31	0.72	0.76
Na_2O	0.23	1.96	0.0	0.21	2.1
K_2O	0.68	1.53	0.21	1.50	1.3
SO_3	2.31	0.61	0.33	0.16	0.21
L.O.I	0.39	9.18	2.93	0.95	5.03

common facilitating additives such as clays, flask, fly ash does not provide the required properties of oil-well mixtures, in particular, they are characterized by high water separation and water loss as well as low sedimentation resistance. In this study, the effect of fine mineral additives of different origin on the properties of lightweight oil well cement was investigated

2. Materials and method

Locally available Ordinary Portland cement (OPC) from Tasluja factory was used in all mixes throughout this research. The used cement conforms to Iraqi Specification No. 5/1984. Also, four types of supplementary cementitious materials (SCM) including natural zeolite (NZ), metakaolin (MK), microspheres (MS) and fly ash (FA) were used in this investigation. The chemical compositions of these binders are presented in Table 1.

The cement used was commercially available ASTM Type I Portland cement with a specific gravity of 3.15 and a fineness of 250 m2/kg. The natural zeolite had a specific gravity of 2.20, a fineness of 330 m2/kg and an average particle size of 16.84 μm. FA was produced in South Africa and it has a specific gravity of 2.22 and a fineness of 410 m2/kg. Also, the used Metakaolin was neither the by-product of an industrial process nor entirely natural. Instead, it was derived from naturally occurring mineral and was manufactured specially for cementing applications. Metakaolin is usually produced under carefully controlled conditions to refine its colour, remove inert impurities, and tailor particle size such that a much high degree of purity and pozzolanic reactivity can be obtained. Furthermore, such controlled conditions lead to a product with a surface area on the order of 12,000 m^2/kg and a specific gravity of 2.5. On the other hand, Microspheres are glass-crystalline aluminosilicate balls, which are formed during flaring of coal at high temperatures. Its average particle size ranges between 1 and 100 μm in diameter and its density is 580–700 kg / m^3.

The determination of the properties of oil-well cements was carried out according to API Specification 10 A [10].

3. Results

Drilling wells with abnormally low formation pressure requires the use of low density mixtures [11,12]. Not only drilling and insulation matrixes should be characterized by this indicator, but also grouting materials. This is due to the abnormality of the pressure of the formation fluids within the well's wall. The use of mixtures of normal density (1,7-1,9 g/cm^3) can lead to significant complications in the design of the well, furthermore, it may reduce the expected production rate of the well. According to API Specification 10 A [10], the density of lightweight mixtures should not exceed 1.65 g/cm^3. There are several ways to achieve such density, but the easiest and cheapest way is the use of additives with a high specific surface area and low bulk density.

One of the criteria while choosing an oil-well cement slurry for individual wells is the physical and performance requirements of the slurry. Given the high water-cement ratio of the mixture, that is a large amount of water, which is necessary to achieve the desired density. Increased attention in modern oil-well cement materials should be paid to reducing the water separation of the slurry, which must draw up to zero [13]. Therefore, when choosing mineral admixtures, we need to pay attention to their properties, such as the

Table 2
Compositions of oil-well cement.

Content, %					
	Composition				
Component	1	2	3	4	5
OPC	70	70	70	70	70
Metakaolin	10	10	10	10	20
Zeolite	–	–	20	10	–
Microspheres	–	20	–	10	10
Fly ash	20	–	–	–	–