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Effect of Amorphous Silica Produced from Pumice and Quartzite on the Flow Characteristics of Drilling Mud

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Abstract

Various additives are introduced to drilling mud to control its flow behavior in drilling operations under the desired conditions. These additives can cause increased drilling costs and environmental damage. In recent years, natural materials have mainly been used in drilling mud to reduce the increasing costs. In this study, amorphous silica was obtained by alkaline extraction method from pumice and quartzite, having a large reserve in Turkiye. Amorphous silica, which is cost-effective and easy to supply, was used in the drilling mud and rheological and filtration tests of the fluids. The results obtained from the study indicate that drilling mud with 8, 9, and 10 % of amorphous silica exhibits promising results.

Keywords:

Amorphous silica, drilling mud, rheology, pumice, quartzite

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Introduction

Technology is developing constantly in the increasing world population. It is known that the energy consumption of countries rises in direct proportion of the increasing population. As it is well known, a large part of energy needs is met from fossil resources, particularly oil and natural gas (Koyamparambath et al., 2022). High-cost drilling operations force scientists to work on cost reduction. Studies to reduce the cost of drilling operations have begun to be carried out intensively.

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These high costs vary according to the drilling mud used, the depth of the drilling operation, and the characteristics of the formations drilled (Ismail et al., 2022).

In drilling operations, the most important matter can be considered as drilling mud. Drilling mud enables the drilling operations to proceed effectively. For the drilling mud to fulfil its duties in the well, the flow properties must be adjusted according to the properties of the formation (Aftab et al., 2017). Flow characteristics of mud, which is in continuous circulation in the well, differ at the entrance and exit of the well. Therefore, viscosity, filtration, pH, gel strength and weight are the most basic properties of drilling mud, and several additives are used to control these properties so that the drilling mud can fulfil its duties. (Avci et al., 2019; Yalman et al., 2021; Yalman et al., 2022a; b). It should be mentioned that apart from the additives research to increase the drilling performance, water used in the formulation of drilling mud also has an important role (Avci, 2018; Avci & Mert, 2019).

Amorphous silica (AS) is produced from pumice and quartzite ores, which have abundant reserves in Turkiye. It is also easy to be produced at a low cost by alkali extraction method, pumice ore, and quartzite ore on the drilling mud. Therefore, in this study, the effects of the addition of amorphous silica were investigated to reveal whether amorphous silica can be used as an alternative mud additive to expensive additives in drilling operations.

Materials and Methods

While pumice, one of the raw materials used in the study, was obtained from the province of Van province in Türkiye. Quartzite, the other raw material used for the study, was obtained from the province of Malatya in Türkiye. Bentonite used in the water-based drilling mud samples to be prepared within the scope of the study was obtained from the province of Çankırı in Türkiye.

In this study, amorphous silica produced from pumice ore and quartzite ore by low-temperature alkaline extraction method and containing at least 98% SiO_2 as described in Aydin et al. (2019a) was used. Then, pumice and quartzite were used as raw drilling mud for comparison.

To reveal the effect of the produced amorphous silica on the drilling mud, water-based drilling mud was prepared separately with the materials from which the amorphous silica is produced. In this context, spud mud containing 6% weight of bentonite was prepared as a reference sample. In the preparation of the reference mud, 700 mL of water and 43.28 grams of bentonite were used according to API standards. The 3-10 (%) additive ratios of the other mud samples prepared were calculated over the reference sample containing the standards. The composition of the mud samples were given in Table 1.

In this study, the American Petroleum Institute (API) API 13B-1 standard was considered as a basis at every stage from the preparation of the drilling mud to the test measurements. The mud formulation consists of bentonite and an increasing amount of AS, pumice ore and quartzite ore (3-10%) (Aydin et al., 2019b). The measurements of the prepared samples were performed considering the test of mud weight, yield point (YP), apparent viscosity (AV), pH, plastic viscosity (PV), gel strength of 10 sec. and 10 min. and filtration.

Table 1. Formulation of the mud samples

Sample Concentrations (wt. %)	AS + Bentonite	Pumice + Bentonite	Quartzite+ Bentonite
3	10.82 g AS 10.82 g Bentonite 700 mL water	10.82 g Pumice 10.82 g Bentonite 700 mL water	10.82 g Quartzite 10.82 g Bentonite 700 mL water
4	14.42 g AS 14.42 g Bentonite 700 mL water	14.42 g Pumice 14.42 g Bentonite 700 mL water	14.42 g Quartzite 14.42 g Bentonite 700 mL water
5	18.00 g AS 18.00 g Bentonite 700 mL water	18.00 g Pumice 18.00 g Bentonite 700 mL water	18.00 g Quartzite 18.00 g Bentonite 700 mL water
6	21.64 g AS 21.64 g Bentonite 700 mL water	21.64 g Pumice 21.64 g Bentonite 700 mL water	21.64 g Quartzite 21.64 g Bentonite 700 mL water
7	25.23 g AS 25.23 g Bentonite 700 mL water	25.23 g Pumice 25.23 g Bentonite 700 mL water	25.23 g Quartzite 25.23 g Bentonite 700 mL water
8	28.84 g AS 28.84 g Bentonite 700 mL water	28.84 g Pumice 28.84 g Bentonite 700 mL water	28.84 g Quartzite 28.84 g Bentonite 700 mL water
9	32.44 g AS 32.44 g Bentonite 700 mL water	32.44 g Pumice 32.44 g Bentonite 700 mL water	32.44 g Quartzite 32.44 g Bentonite 700 mL water
10	35.6 g AS 35.6 g Bentonite 700 mL water	35.6 g Pumice 35.6 g Bentonite 700 mL water	35.6 g Quartzite 35.6 g Bentonite 700 mL water

Results and Discussion

Results obtained when the AS obtained from pumice and quartzite by alkali extraction method is added to the water-based drilling mud at the same weight ratios under the same conditions were given in Table 2. It was determined that the prepared samples largely met the API standard at 8%, 9% and 10% additive rates. It was also determined that it provides the YP/PV ratio, which is one of the important parameters of this standard in all additive ratios. When the values obtained for filtration, which is another important parameter, were examined, it was seen that they met the standard reference value at 8%, 9% and 10% additive rates, thus reducing the undesirable high fluid loss in drilling operations. Analysis results of the samples prepared with the pumice and quartzite at the same weight ratios under the same conditions are given in Table 3 and Table 4, respectively.

Table 2. Results of amorphous silica + bentonite mud samples

Concentration of amorf silica (%)	pH	AV (cP)	PV (cP)	YP ($lb/100ft^2$)	10 sec/10 min Gel Strength ($lb/100ft^2$)	Filtration (mL)
3	7.6	2.0	1.0	2.0	1 / 2	90
4	7.71	2.0	1.0	2.0	1.2 / 2.5	90
5	7.75	2.25	1.0	1.25	1.5 / 2	80
6	7.89	2.75	1.5	2.5	1 / 1.5	45
7	7.91	2.75	1.0	3.5	1 / 2	25
8	7.95	3.5	1.5	4.0	1 / 3	15
9	8.0	6.5	4.0	5.0	5 / 6	12
10	8.16	6.5	2.5	8.0	5 /6.5	10

Table 3. Results of pumice + bentonite mud samples

Concentration of amorf pumice (%)	pH	AV (cP)	PV (cP)	YP ($lb/100ft^2$)	10 sec/10 min Gel Strength ($lb/100ft^2$)	Filtration (mL)
3	8.1	2.25	1.5	1.5	1 / 2.5	100
4	8.12	2.25	1.5	1.5	1.2 / 2.5	100
5	8.2	2.5	1.5	2	1.5 / 2	90
6	8.2	2.75	1.5	2.5	1 / 1.5	55
7	8.25	2.75	1	3.5	1 / 2	30
8	8.26	2.75	3.5	2	1/ 3	17
9	8.42	3.25	4.5	2	1 / 2	16
10	8.51	12.5	9	7	3.5 / 4	10

Table 4. Results of quartzite + bentonite mud samples

Concentration of quartize (wt. %)	pH	AV (cP)	PV (cP)	YP ($lb/100ft^2$)	10 sec/10 min Gel Strength ($lb/100ft^2$)	Filtration (mL)
3	8.8	2.5	2.5	0.25	1 / 1.2	80
4	8.7	3.25	3	0.5	1.5 / 2	70
5	8.68	5	4.5	0.5	2 / 2.2	55
6	8.65	6.5	5	3	2.2 / 2.5	45
7	8.7	6	3.5	5	2 / 2.5	35
8	8.65	9	8	2	1.5 / 3	30
9	8.64	15.5	13	5	3 / 3.5	28
10	8.55	25	22	8	5 / 5.5	25

As a result of the analyzes made, it has been seen that pumice ore and quartzite ore meet some standards in water-based drilling mud at 8%-10% additive rates. However, due to the physical and chemical properties of these additives, it has been determined that the direct use of the additives in the drilling mud will hinder the efficient process of the drilling operation. It can be concluded that pumice ore and quartzite ore are not suitable to be used directly in water-based drilling mud. It is also suggested that AS can be used as an alternative mud additive to expensive additives in drilling operations.

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Author Contributions

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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