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Jan Macuda*, Sławomir Wysocki*, Magdalena Gaczoł**

NEW MUD FOR HYDROGEOLOGICAL DRILLING***

1. INTRODUCTION

Groundwater is essential in all areas of society, the environment and industry [1]. Each of above mentioned, for various purposes, make use of huge reserves of the water obtained from underground deposits. Every year a great number of water wells is drilled for home-owners, extending metropolitan areas or industrial districts. Moreover, water demand is growing at an enormous rate in view of industry development and human population growth. Due to this, hydrogeological drilling is an important concern of the drilling industry and its range is global.

Hydrogeological drilling mainly deals with shallow boreholes drilled through various types of geological formations. However, new technologies allow exploitation from larger depths what require more than just standard native mud (drilling fluid in which formations being drilled are suspension medium) [2]. For the sake of most effective drilling processes and safety preservation, it is vital to use the best working drilling fluid [3]. This fluid should fulfil standard functions, like cuttings transport or formation pressures balance, although the fundamental influence on drilling mud selection has a type of drilled formation and technique and technology of drilling. Each borehole varies in those aspects. Yet, two of the factors affecting the hydrogeological drilling process that are unchangeable can be distinguished.

Firstly, it is major to stick to the strict environmental protection regulations – mud should not pollute the environment. Thus, it should not threaten the valued groundwater for it has a direct contact with the aquifer [4]. Under those circumstances the preferred mud is water-based or air-based fluid, its ingredients are environmentally friendly, not contaminated, natural products.

* AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland
** AGH University of Science and Technology, Faculty of Drilling, Oil and Gas – PhD Student, Krakow, Poland
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The following factor is related to clogging phenomenon – settling of solids in pore channels. It is the main reason for reservoir rock damage causing a decrease of rock permeability and porosity. In order to avoid irreversible impact caused by solids originated from drilled formations, bridging materials with adequate granulation are applied as an addition to the mud [5]. Those, most recently carbon-based, compounds creating filter cake clog the near-well zone during drilling period. However, after the borehole is successfully drilled and the hole is cased, the drilling fluid products must be removed for the maximization of well yield. This process is called well development. Underdeveloped wells decrease exploitation efficiency due to limited open area in well yield. While cooling, clearing, stabilizing are essential for successful hole completion, in water well drilling the overuse of additives can make the removal of the drilling fluid residues more difficult during well development [6]. Hence, in order to provide further efficient production, drilling fluid should be easily removable. It can be achieved using biodegradable products and bridging materials as mud ingredients. Low concentration of drilling fluid results in thinner filter cake simplifying and shortening the well development process. Additionally, it is beneficial from an economic point of view.

Properly designed polymeric mud, being multifunctional, fulfils the requirements for hydrogeological drilling. Its most relevant advantages are: regulation of filtrate loss in a wide range, the enhancement of rheological properties, the improvement of borehole wall stability and selective flocculation [5]. Depending on changeable conditions after mixing the basic drilling fluid, its properties can be enhanced by additives [7].

2. CHEMICALS APPLIED IN THE STUDIES

GRX mud – technical grade – Polymer Technologies – one-sack product, biodegradable mud for hydrogeological drilling.

Mikhart 40 – technical grade – BDC – carbon bridging material with an average granulation of 30 μm [8].

NaCl, $CaCl_2$, $MgCl_2$ – pure – Avantor Performance Materials Poland S.A.

3. METHODOLOGY OF THE RESEARCH

The research were performed according to Polish and international standards (API Spec.) [9]. Linear swelling tests have been achieved with GRACE Instrument M4600 HPHT Linear Swell Meter.

4. TECHNOLOGICAL PARAMETERS OF GRX MUD

Preliminary research consisted of measurement of the GRX mud technological parameters. Tests were undertaken for five different concentrations of the mud range from 1% to 3% by weight (Fig. 1).

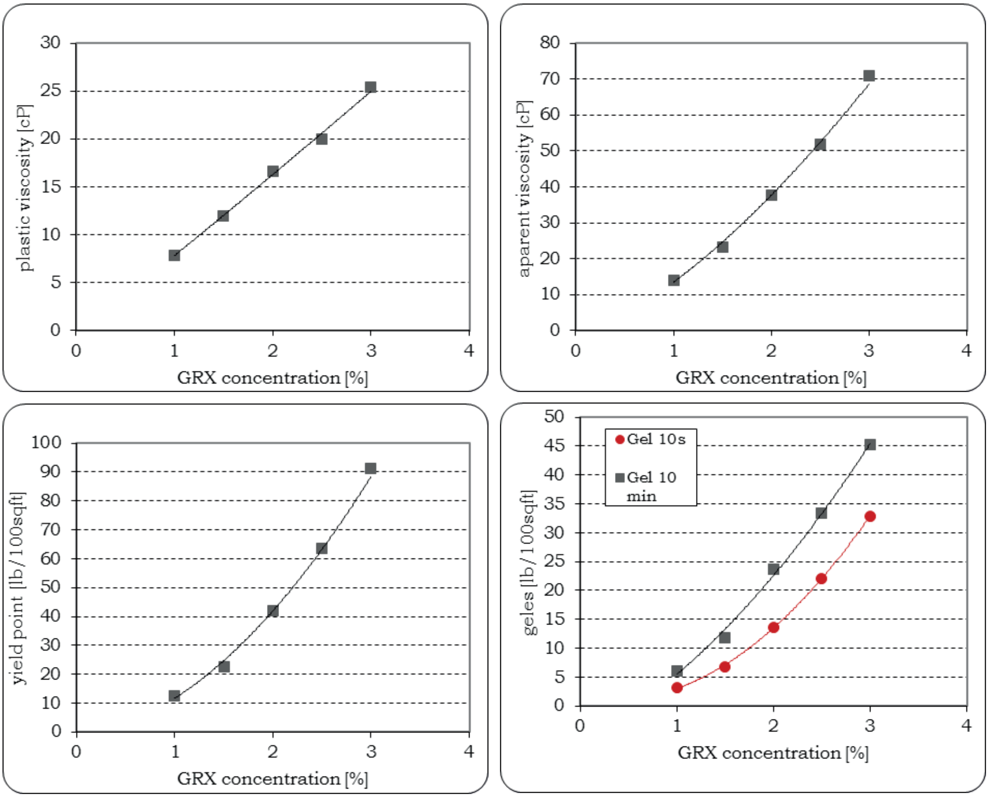


Fig. 1. Technological parameters of GRX mud in different concentrations

The obtained results show that the studied mud reaches good technological parameters beginning with lower concentrations (1–1.5% by weight). A progressive increase of the GRX concentration results in he quick raising of technological parameters. Due to this, even a small dose of the GRX product easily enables its rheology improvement. A small amount of the ingredients applied in GRX mud simplifies both its successful control and adjustment of individual technological parameters to specific conditions. Furthermore, the GRX mud is less complex than standard multi-ingredient mud. It also contributes to drilling conditions improvement and drilling costs decrease.

5. INFLUENCE OF BRIDGING MATERIALS ADDITION

GRX mud is characterised by low density of 1.01–1.02 g/cm^3. It is advantageous in circumstances of shallow borehole drilling, yet quite frequently occurs a necessity of increasing mud density e.g. in order to provide borehole wall stability. In view of this issue, tests of weighting material influence on the GRX mud technological parameters have been conducted. A carbon bridging material Mikhart 40 in concentration of 10% by weight was used as a weighting material. Outcomes are summarized in Figure 2.

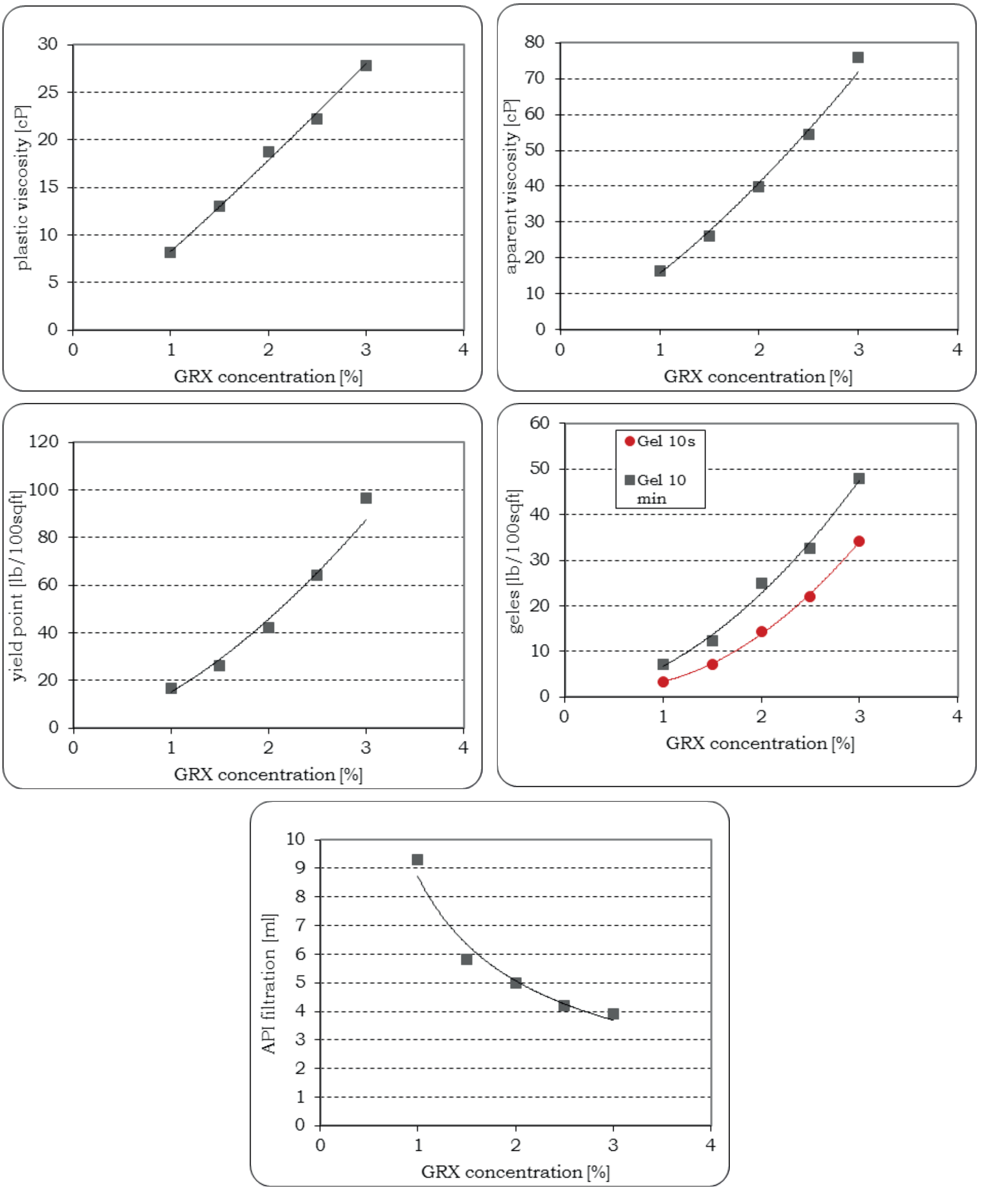


Fig. 2. Influence of bridging material addition on technological parameters of GRX mud

Tests that have been conducted indicate that GRX mud with the addition of carbon bridging material exhibits good technological parameters and low filtrate loss. The density of the tested muds is in the range of 1.11–1.13 g/cm^3.

The change of the GRX mud technological parameters under the influence of carbon bridging material is presented for 1.5% GRX by weight (Fig. 3).

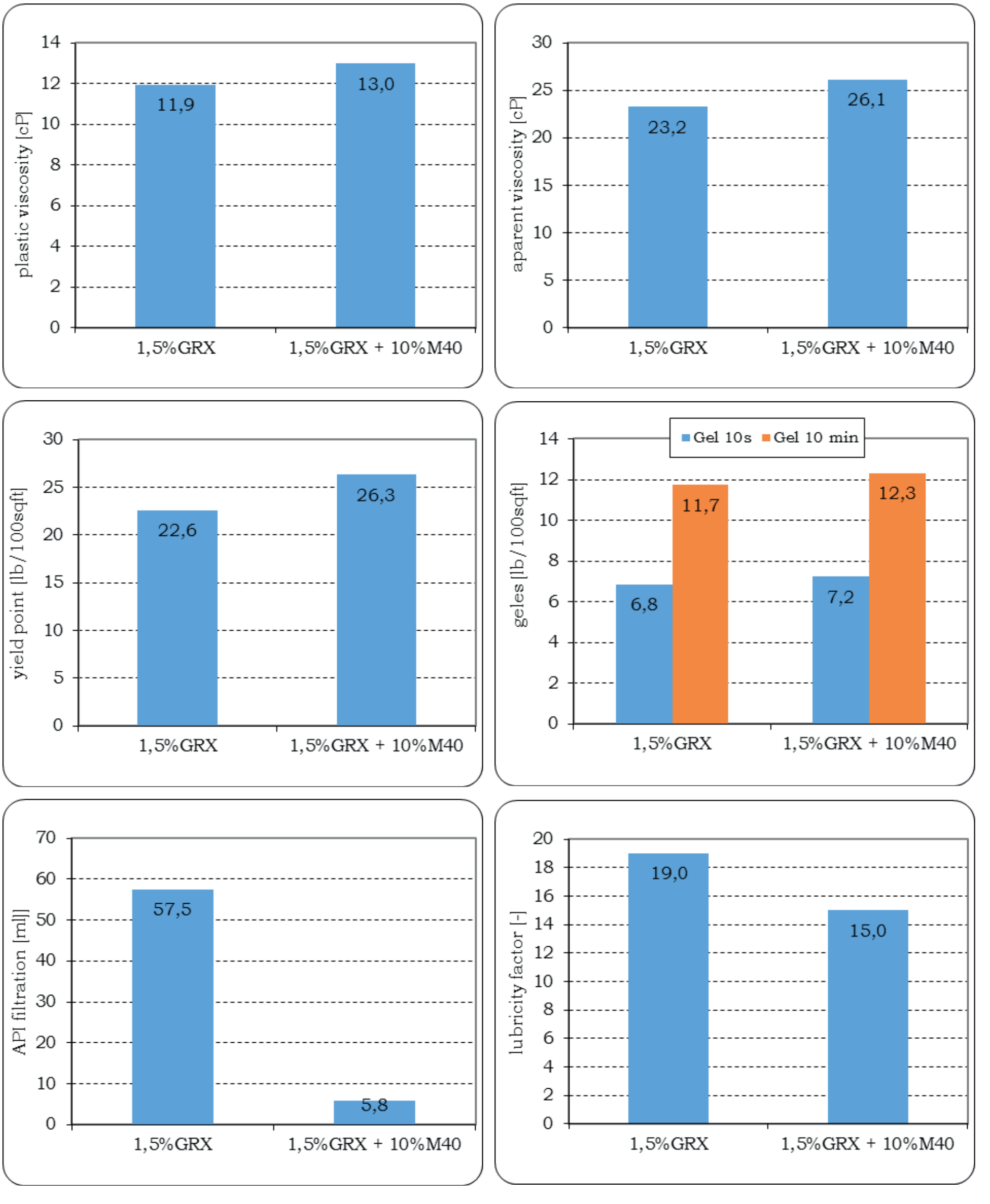
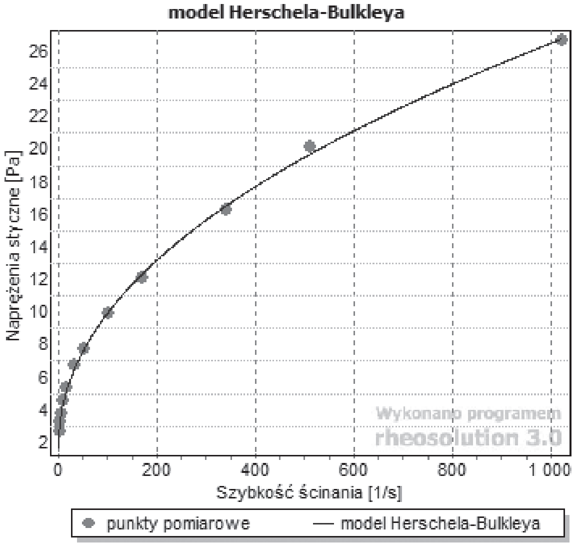


Fig. 3. Comparison of technological parameters of GRX mud
without and with bridging materials addition

Test findings show that the addition of carbon bridging material causes a minor increase of the GRX mud rheological properties. However, a noticeable decrease of both filtrate loss volume and lubricity factor is a beneficial effect.

6. RHEOLOGICAL MODEL

Subsequently, the rheological model has been designed for the studied mud. The match has been found with RheoSolution 3 computer application [10]. Test outcomes for 1.5% GRX by weight with addition of carbon bridging material are presented in Figure 4.



Najlepiej dopasowany model:
Herschela-Bulkleya

$$\tau = \tau_{yHB} + k_{HB}\gamma^{n}$$

Współ. korelacji Pearsona R=0,9997
korelacja pełna

Współ. korelacji Pearsona	R	**0,9997**	pełna
Współ. Fischera-Snedecora	F	**16149,60**	[-]
Suma kwadratów	U	**0,39**	[-]
Granica Płynięcia	τ_{yHB}	**1,6932**	[Pa]
Współ. konsystencji	k_{HB}	**0,9166**	[Pa*s^{0,4776}]
Współ. kształtu	n_{HB}	**0,4776**	[-]

Fig. 4. Rheological model for GRX mud with a bridging material addition

On the basis of an established match, it has been noted that the studied mud has the best correlation with the Herschel–Bulkley model. GRX mud is characterised by relatively low values of viscosity in high shear rates and relatively high values of viscosity in low shear rates. LSYP value for exemplary mud is 6 [lb/100sq ft], whereas LSYP/YP coefficient is 0.23 [–].

7. THERMAL RESISTANCE

In order to investigate GRX mud's resistance to temperature, in conditions of successive heating and cooling of the mud, its rheological behaviour was examined. A test was undertaken for 1.5% GRX by weight with carbon bridging material addition. The findings are presented in Figure 5.

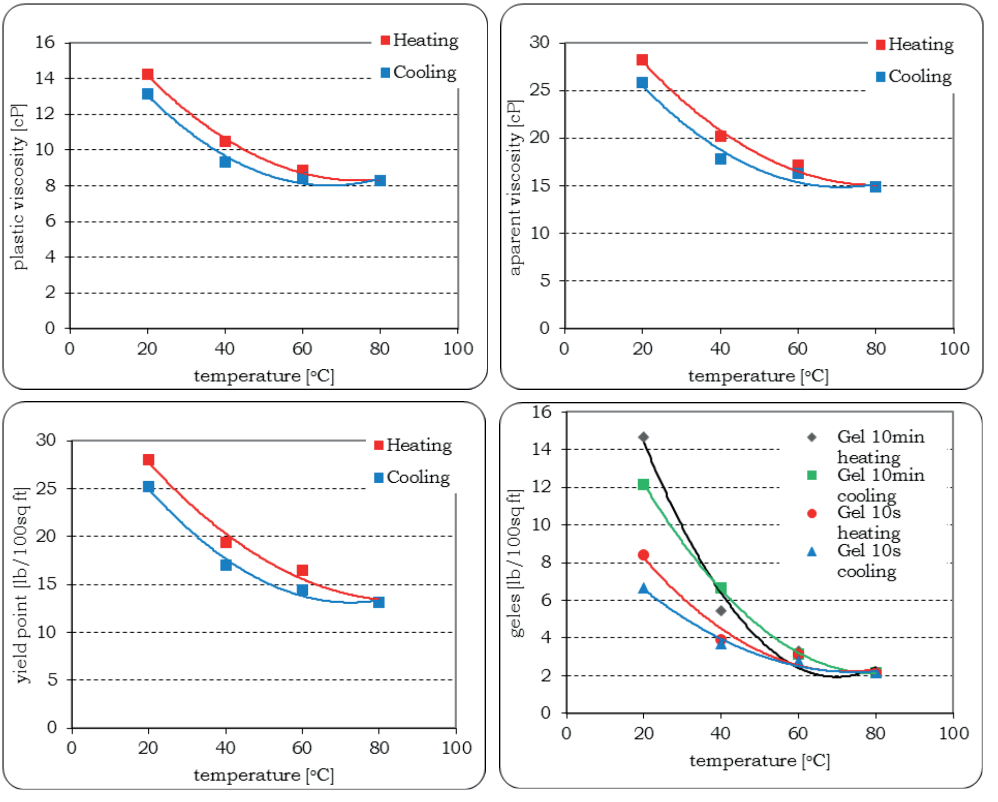


Fig. 5. Thermal resistance of GRX mud

An analysis of the findings indicates that tested fluid rheological properties decreases while being heated, whereas being cooled reaches values similar to initial ones. This behaviour proves GRX mud's thermal resistance.

8. SALTS CONTAMINATION

To ensure the verification of GRX mud's resistance to salt contamination, tests of NaCl, $CaCl_2$, $MgCl_2$ influence on rheological properties of 1.5% GRX by weight with carbon bridging material addition were conducted. The test results are summarized in Figures 6–7.

The rheological properties of the studied mud increased after the addition of sodium chloride of 5% by weight. It can be noticed that a further increase of the salt concentration does not result in serious modifications of mud technological parameters.

The results indicate that GRX mud is resistant to divalent ions contamination. After an addition of calcium and magnesium ions to the mud, it can be observed only an insignificant decrease of the rheological properties.

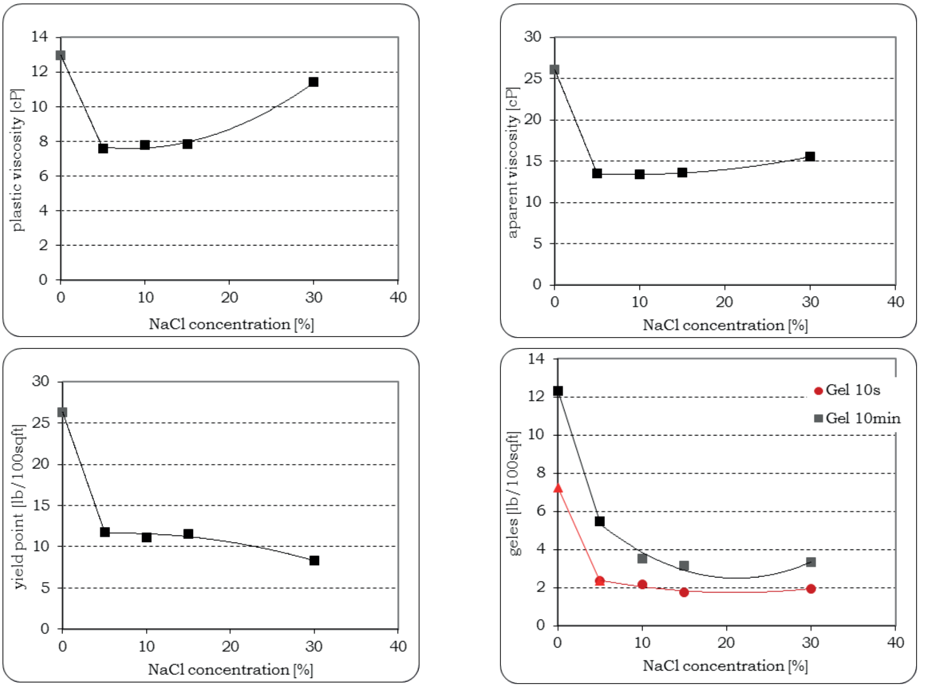


Fig. 6. GRX mud resistance for monovalent ion contamination

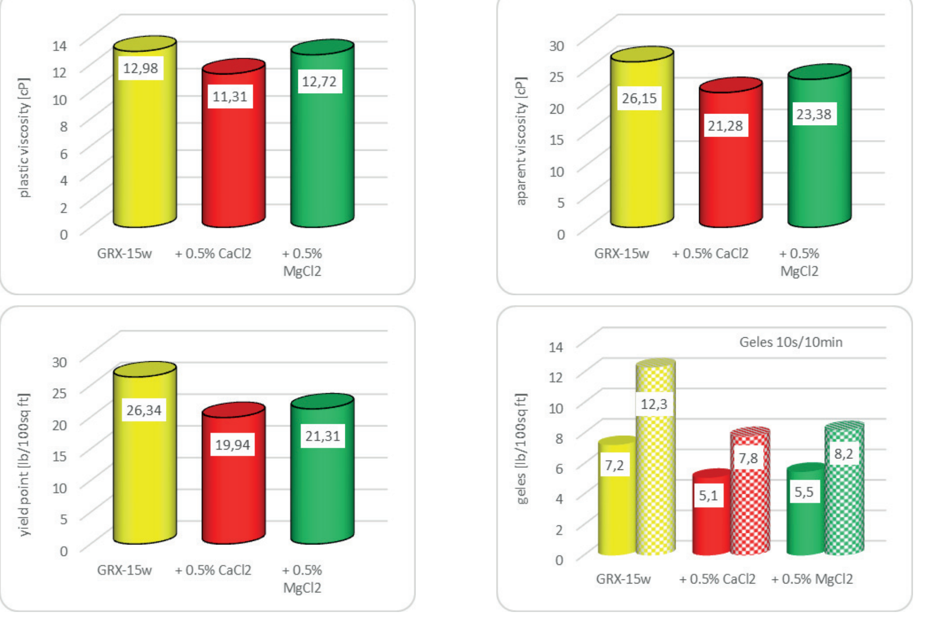


Fig. 7. GRX mud resistance for divalent ions contamination

9. SHALE SWELLING

In order to investigate the GRX mud impact on shale rock, a linear swelling test has been conducted on Miocene shale under influence of 1.5% GRX by weight both with and without carbon bridging material addition. The results are presented in Figures 8–9.

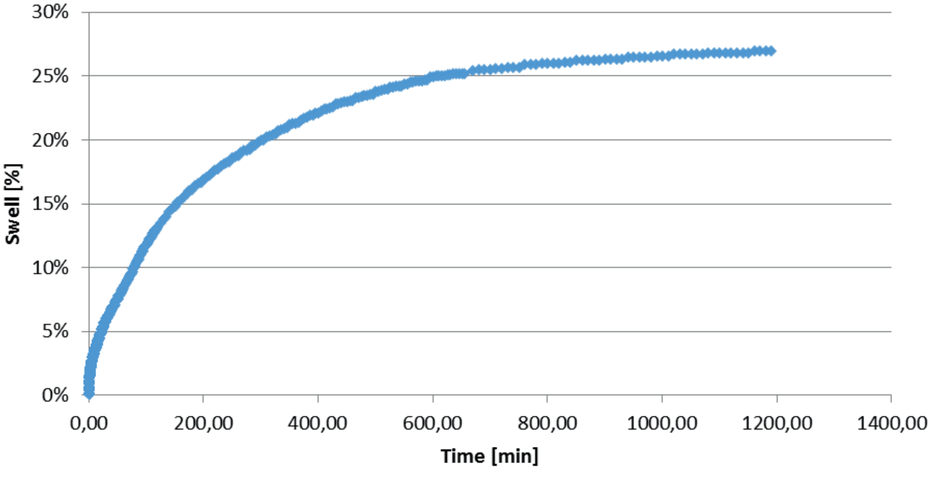


Fig. 8. Linear Swell Test of Miocene shale under the influence of GRX mud

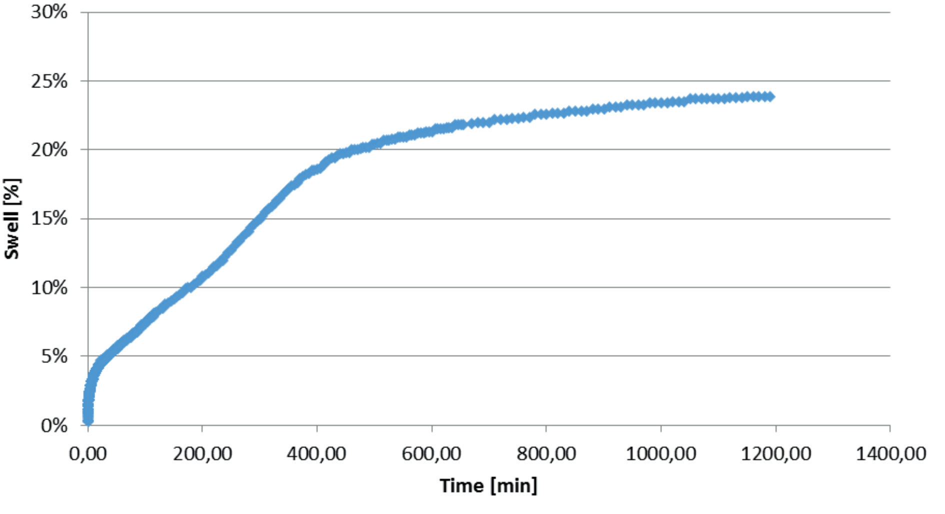


Fig. 9. Linear Swell Test of Miocene shale under the influence of weighted GRX mud

Based on test results, it has been found that GRX mud does not inhibit hydration of shale rocks. The addition of carbon bridging material causes an irrelevant decrease of the Miocene shale swelling.

10. CONCLUSIONS

Summing up the findings, it can be concluded that GRX mud is characterised by good technological parameters. Furthermore, it is resistant to both temperature and multivalent ions contamination.

Even a small amount of the ingredients enables easy regulation and control of the mud technological parameters. Thus, it contributes to parameter improvement and additionally drilling costs decrease.

An analysis of the obtained results indicates that the GRX mud may be successfully applied in hydrogeological drilling.

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