PROCOR CHEMICALS, INC.

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Pozzolanics

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Novel Applications of Pozzolans to Treat Wellbore prior to Cement, Casing and While Drilling to Prevent Overburden Stress Fractures

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Abstract

This study is focused on the application of novel pozzolans (superplasticizers) ahead of cement, prior to casing and while drilling to treat and prevent wellbore fracture due to overburden stresses. This study is a combination of quantitative and qualitative analysis based on laboratory and field applications of pozzolanic materials in the construction of wells.

Pozzolans have long been applied to construction materials in order to improve lifespan and compressive strength. The application of pozzolanic materials goes back over 2000 years to the construction of Roman Aqueducts, buildings and roads known for their longevity and ability to resist corrosion and stress. These materials cover a broad range of naturally occurring and man-made materials. The most common pozzolanic materials used in drilling today include Bentonite, Kaolin, and Fly Ash. Pozzolans when combined with Portland Cement have been shown to increase the compressive strength and durability dramatically. Pozzolans are currently applied globally in cementing applications for HTHP, high loss zones and more.

This paper will examine the application in the drilling phase as an applied treatment during drilling for the reinforcement of the wellbore as well as to treat induced losses. The study will review cases for use of Novel Pozzolans for drilling, pre-cement, casing and for production zones the application of Novel acid soluble pozzolans for similar purposes. These applications validate the application of these materials beyond cementing into the drilling phase and wellbore construction for reducing backside pressure, reducing days on losses, reducing sidetrack, increasing operational ECD while drilling and cementing and achieving top of cement without inducing losses due to overburden in tight ECD window environments.

Deepwater environments provide a unique environment for the application of these novel materials as they offer some of the highest overburden environments with greatest operating costs and daily operating costs. Thusly this study has shown the applications have saved operators on multiple wells and over long periods many days and millions in operating costs with proven prevention of losses in field studies where wells were compared for offset value over a period of time. Multiple operators have adopted this technology as a result and there is a long track record of use while there are few papers on the subject. The purpose of this paper is to illustrate the best practices as well as new technologies and state of the art when it comes to the development of the latest in pozzolanics for these applications.

Background and History

One of the most critical stages in the drilling and completion of oil or gas wells is cementing job. The application is incorporated into many scientific and engineering disciplines (Nelson, 1990). In 1756, a British engineer, John Smeaton, first developed Portland cement, which is currently the most common type of cement being used worldwide. Portland cement is an example of hydraulic cement from a synthetic mixture of lime (C_aO), clay, silica (S_iO_2), alumina (Al_2O_3) and water to form hydration which is generally conducted at room temperature (Aspdin, 1824).

In 1850, Isaac Charles Johnson produced the actual prototype of Portland cement in England. However, cement production has been rapidly spreading over Europe, United States, China, India, Vietnam, and Egypt. Depend on their application, Portland cement is manufactured, classified, and specified based on established systems known as the American Society for Testing Materials (ASTM). American Petroleum Institute works with the International Organization of Standards (API-ISO) to meet specific physical and chemical standards (Nelson and Michaux, 2006). To accommodate various conditions, cement additives are required to adapt the system's behavior by adding accelerators, retarders, extenders, weighting agents, dispersants, fluid-loss control agents, lost-circulation control agents, and specialty additives (Nelson et al., 2006).

One of the critical factors in designing well cementing is when the hydrostatic pressure is less than the fracture pressure but slightly higher than the formation pressure (Mata et al., 2006). The main challenge is a narrow gap between the pore and fracture gradients at the low formation gradients, usually present in weak formations such as shallow depth, deepwater environments, or depleted zones (Luzardo et al., 2015). In addition, low formation fracture pressure resulted in loss circulation, which further leads to permanent formation damage, well kick, blow out, and well abandonment (Miller et al., 2013; Meza et al., 2017).

To mitigate loss circulation, several solutions have been implemented in the field include secondary cementing (Hassan et al., 2019; Addagalla et al., 2020), expandable liners (De Grandis et al., 2013), nanoparticle-based chemical treatment (Wagle et al., 2018), cross-linked polymer gel systems (Hashmat et al., 2017), low-solids shear dependent cement (Duffy et al., 2017), and use of lightweight cement systems (Pernites et al., 2020; Adjei et al., 2021). Lightweight cement is preferred (Nelson and Guillot, 2006), specifically pozzolans, discovered as sustainable, cost-and time-effective (Katare and Madurwar, 2020).

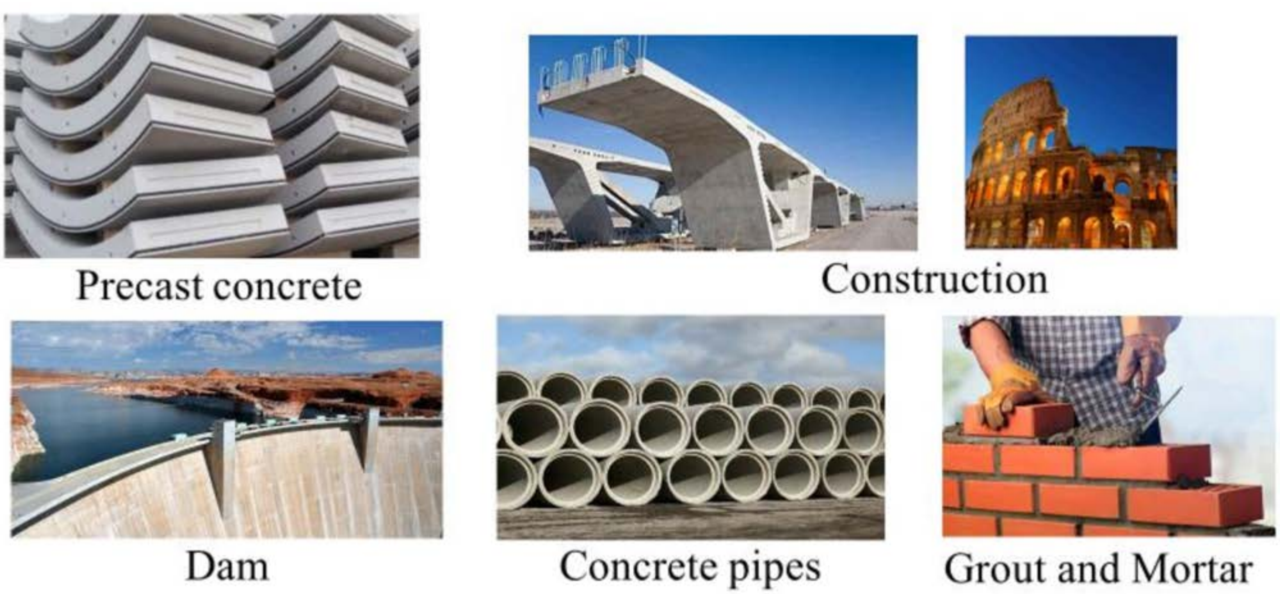


Fig. 1—Pozzolans Applications

The application of Pozzolans has been discovered in the Roman period in the 18th and early 19th centuries (Caijun, 2001), see Fig. 1. Pozzolanic materials are either amorphous siliceous or siliceous and aluminous that reacts with calcium hydroxide and water at room temperature, known as a pozzolanic reaction (Walker and Pavia, 2010). Pozzolans are a type of extenders that generally have a slightly lower specific gravity (2-3 g/cm^3) than cement (3.2 g/cm^3) and very fine particles of ground pumice or fly ash (Heathman and Crook, 1994). Thus, pozzolanic materials reduce the amount of Portland cement (Bustos et al., 2012), strengthen the matrix, and decrease ceent permeability (Nelson and Gulliot, 2006).

As shown in Fig. 2, examples of pozzolans such, as natural pozzolana (Massazza, 2002; Uzal et al., 2010), silica fume (Mostafaa et al., 2001), fly ash (Smith, 1956; Paya et al., 2001), rice husk ash (Walker and Pavia, 2010), calcined clay (Murtaza et al., 2020), and metakaolin (Ramezanianpour and Jovein, 2012) have been used extensively and proved for long term compressive strength to concrete. Pernites studied that Pozzolanic materials with a high amount of silica, aluminum oxide, and iron oxide are more reactive to calcium hydroxide to establish a higher compressive strength in a short period of time (Pernites et al., 2018).

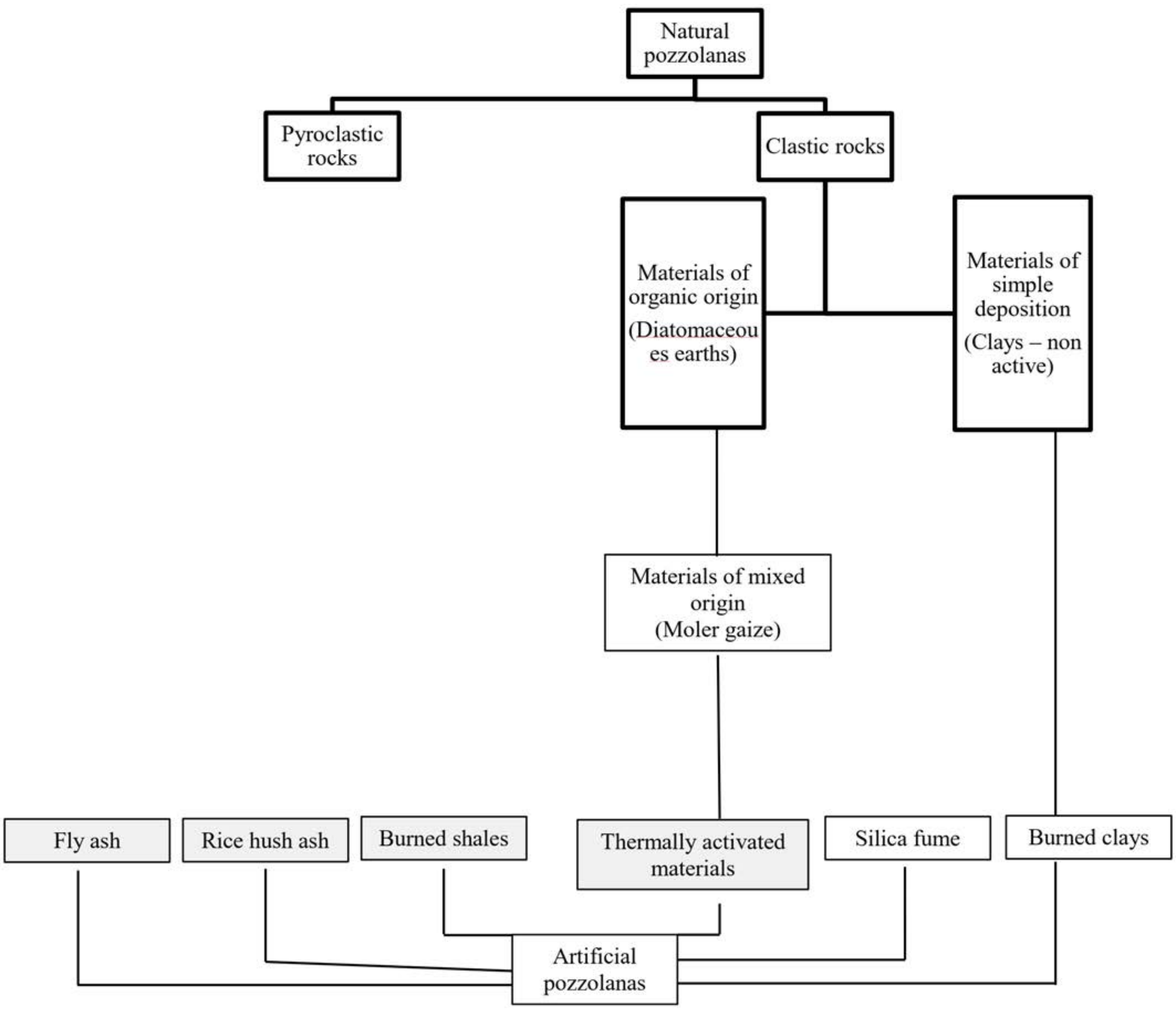


Fig. 2—Pozzolan Materials and origins

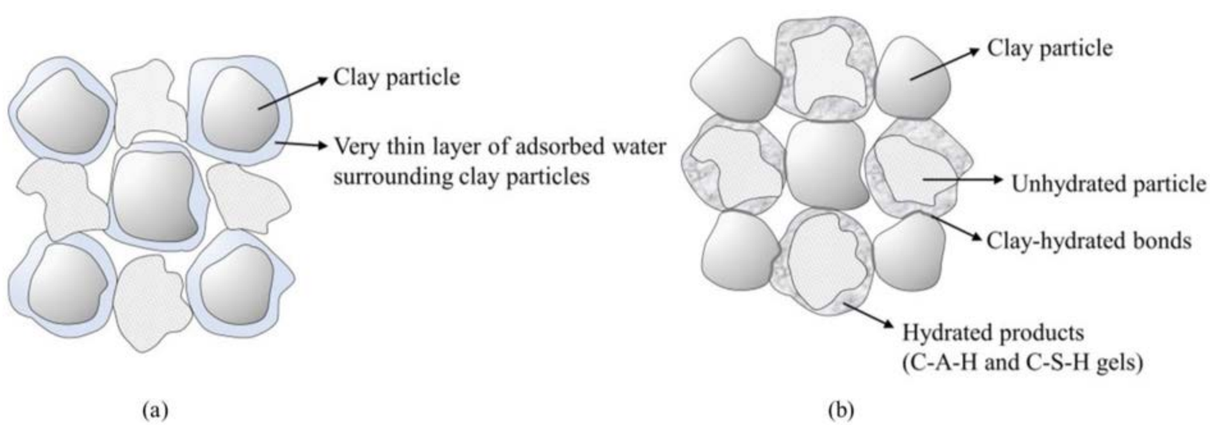
Evaluation of pozzolans reactivity is a complex problem (Currell et al., 1985). It indicates how responsive and effective pozzolanic materials were mixing with Portland cement which depends on chemical or physical or mineralogical composition, microstructure, pore size distribution, the ratio of lime to pozzolan, temperature, mix design, curing conditions, water content, type, and proportion of the hydration products, and the size of the particle's surface area (Lumley et al., 1996; Massazza, 2007). Several techniques have been developed to investigate lime-pozzolan reactions, including an early rate of pozzolanic reaction, chemical activity to measure conductivity or resistivity, calorimetry, and mechanical activity index (Ma et al., 1997; EN 450-1, 2005).

Laboratory studies to predict field performance in an actual downhole condition have been challenging to extrapolate (Santra et al., 2009). A high compressive strength assessment was subjected to squeeze pressures applied to the pill (Barry, 2017), which is also very sensitive to the water added (Barry, 2019). Nelson conducted a laboratory test with the most prolonged test duration for cement retrogression in about one year (Nelson, 2006). For field studies, lost circulation treatments for naturally fractured, vugular, or cavernous formations (Canson, 1985) and unconsolidated formations (Fidan et al., 2004) require further considerations, including reviewing and evaluating several alternative drilling.

Cementing is typically conducted during drilling and completion stages to avoid wellbore instability and isolate undesired intervals. In order to improve cement integrity, several techniques have been attempted such as by adjusting the water to cement ratio, adding Pozzolanic materials, and altering the cement type (Aiken and Wildgust, 2009). In addition, Abid performed and evaluated the application of Palm Oil Fuel Ash as a promising supplementary material to be mixed with the Class G cement (Abid, 2019); natural pozzolan is used in lightweight drilling cement slurries (Larki et al. 2019).

This study aims to review, illustrate, and examine the latest applications of novel pozzolans for drilling, pre-cement, casing, and production purposes in Deepwater environments with the greatest daily operating costs. Deepwater environments provide a unique environment with high pressure and high temperature (HTHP) that cause significant challenges to the operators. By the presence of novel pozzolans, the applications have saved operators on multiple wells over long periods of many days and millions in operating costs with proven prevention of losses in field studies where wells were compared for offset value over a period of time.

Pozzolanic Reactions



(a) prior to hydration and (b) after a few weeks curing, the cement has reacted with the soil water and produced hydrated cementitious gels. (Kurtis 2007).

Fig. 3—State of Solid Mixed with Cement (Drawings By Estayana, 2021)