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IMPROVING THE EFFICIENCY OF LIME PRODUCTION PROCESS USING FLOCCULANT

7.1 INTRODUCTION

In the Limestone Production Plant "Trzuskawica" the process of pipeline transport of lime slurry is carried. Limestone slurry flows by turbulent traffic and is usually accompanied by a moving bottom sediment. Limestone slurry is directed to the settling tank (natural reservoir), in which the solid-phase fraction sediments and the excess water, through the transfer system, is recycled back to the process of hydrotransport. This method is very wasteful, since sedimentation tanks are located at a considerable distance from the plant, which increases costs of transport. Moreover, expensive and technically complex is remove of waste material from the sedimentation tank. Also, the amount of the recovered water from settler tank is not satisfactory. For these causes, it is reasonable to use a different technology that allows to shorten the distance of transported hydromixture and recover more water from the hydrotransport process. This will be possible when the solid-phase is separated from hydromixture, which will be stored in the plant on the heaps [6, 7].

Sedimentation is often used mechanical method of purifying water from suspended substances. It consists in sinking denser, dispersed solid phase in a mixture of two phases to the bottom under the influence of gravity force, which allows their separation. The limitations of the sedimentation usually occurs when we are dealing with very small diameters of the particles and the sedimentation velocity (terminal velocity) is low, which increases the time of clarifying [5].

On the process of sedimentation occurrence affect many factors, including: the solid phase concentration, the viscosity and density of the solid phase and the carrier, the type of used coagulant (flocculant), the nature of the resulting flocks or agglomeration abilities, the type of traffic hydromixture – laminar, turbulent, the type of removed slurry and the colloidal substances, the process of diffusion, etc. [3].

7.2 DIAGNOSIS OF THE HYDROTRANSPORT PROBLEMS IN THE PLANT

In the analyzed case decanted from the precipitate water is recycled back into the process, and collected in the bottom of the tank sludge is periodically removed. This waste material is characterized by high fragmentation and strong hydration, which is why it is not used economically. Waste is deposited on the waste disposal site located at the area of the plant. This method of waste disposal is time-consuming and burdensome. It forces, among other things, the need of downtime in devices, manual or mechanical removal of waste material, which have a high specific gravity (about 2 kg/dm^3). This entails the growth of costs of functioning of the plant.

Another problem is the high consumption of water. It is estimated that in the whole process at all stages of production, from raw material feed applications from the mine through the successive stages of crushing and breaking, screening and washing, the amount of consumed water is equivalent to 400 m^3/h. This water comes from its own shots in Sitkówka. Until now, water after pre-purifying from the smallest fraction was discharged into the Bobrza river.

The solution to the problems associated with water purification from fine particles of silty phase with diameters not exceeding the 0.0875 mm is the use of flocculants dispensing station in the system. The functioning of the installation rests on adding to the contaminated water production (hydromixture) the solution of flocculant, chemical accelerating the clarification. Synthetic polymeric substances (called flocculants) cause the flocculation process in which are forming the flocks in a layer maintained in a suspended state. The fine particles are bound in large flocs, which then fall by the gravity to the bottom of the settler tank. The clarified water is directed back to the process, while the concentrated sludge at the bottom of the tank can be deposited on the plant`s waste disposal site.

7.3 THE MECHANISM OF FLOCCULATION

To flocculation occurred must appear direct collisions between suspended particles, therefore must be defeated the forces of repulsion. The energy of these forces depends of the mutual distance between particles and becomes important at very small distances. These distances can be defeated by using the so-called "Brownian motion", the chaotic motion of particles in the fluid caused by collisions of slurry with the molecules of the liquid. Brownian motion is observed for the microscopic, smaller than a micrometer particles of slurry, regardless of their type. The molecules move constantly and their movement is unabated. Speed of movement is greater for smaller particles and higher temperature. Flocculation based on this phenomenon is called "perykinetics flocculation ". However, if the movement of the solution is enforced, eg by mixing, then we speak about the "orthokinetic flocculation" [4].

During the flocculation process occurs, between particles are created bridges. Great-chain-molecules of typically synthetic polymers are absorbed on the surfaces of the particles causing them to crosslinking. The possibility of bridges formation is dependent on both the number of free polymer groups remaining at the disposal as well as the degree of filling the particles of the polymer. There is an optimal concentration of the polymer, below which due to the shortage and above which because of the availability to adsorption on the particles, the cross-linking is incomplete [1].

Transport resulting from different particles velocity is also based on different sizes of flocks, which results in significant differences in the rate of subsidence during the sedimentation. They cause additional collisions and therefore an increase in flocks, which leads to the formation of faster falling aggregates [5].

However, the formation of flocks in the pipes due to the possible speed of movement for each pipe diameter has its limits, at which on the one hand there are deposits of thickened sludge, on the other hand take place the destroying of flocks [2].

7.4 THE MECHANICAL PROCESS OF SEDIMENTATION USING A FLOCCULANT

The sedimentation process with using a flocculant in this production enterprise is limited by the conditions resulting from technical parameters of installation and human factor. Diagram of radial AquaCycle sedimentation tank installed on the premises of the ZPW Trzuskawica is shown in the figure 7.1.

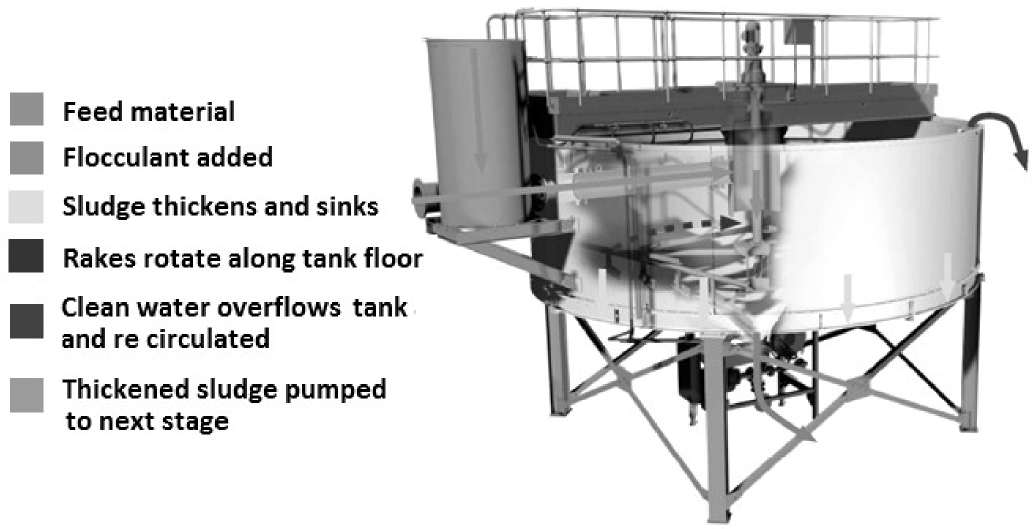

Fig. 7.1 Scheme of radial settler tank with coagulation chamber

Source: AQUACYCLE Brochure: Water Treatment System. /www.cdeglobal.com/

The process of preparing flocculant must last enough long because of the maturing of flocculant for 45 minutes at 20 centigrade degrees. Pre-mixing of flocculant occurs in the closed pipeline connecting the flocculant dosing station with a settler tank. Flocs are formed in the central circular chamber of the sedimentation tank equipped with a stirrer and the stators, of which the water flows radially outwards. The peripheral speed of the stirrer amounts about (0.5-1.5) m/s. Uniform distribution of the coagulant throughout all the volume of the tank provides to maintain the homogeneous system. In the sedimentation tank thickening of sludge occurs in a continuous manner, which means that there is a constant supply of raw sewage sludge with continuous discharge of supernatant liquid and the sludge. Efficiency of the tank, shown in the figure 1, is 400 m^3/h. Other specifications of the tank are: internal diameter: 10.5m, depth 4.4m, weight of the drum: 20t, total weight of the tank: 200t.

7.5 RESEARCH METHODOLOGY

The study aimed to determine the optimal dose of flocculant, the addition of which, in possible short time occurs the sedimentation of solid particles in hydromixture. The results were also analyzed in terms of cost-effectiveness of the application of flocculant in continuous motion of installation. The tested material is limestone mixtures with a density of 2720 kg/m^3, which mostly constitute the particles of dust fraction (76.55%) with diameters in the range (2-50) um. The percentage content of clay fraction having an average particle diameter of less than 2 microns is 16.4%, while the phase of the sand with a diameter of grains in the range greater than 50 microns is 7.05% of all particles.

The analysis of chemical composition of the solid particles was performed. In terms of the chemical, tested sediment consists mostly of calcium oxide (CaO – 73.64%) and silicon dioxide (SiO_2 – 13%). Other chemical compounds included in solid particles constitute a small share, and are as follows: MgO – 0.61%, Fe_2O_3 – 0.32%, Al_2O_3 – 1.11% and SO_3 – 0.28%. Humidity of tested samples was 96.67%.

Before starting the measurements of sediment, resulting from the sedimentation process of adding a flocculant, it was necessary to determine the mass concentration of hydromixture (Cm). It specifies the percentage content of solids (sludge mass) in total weight of the hydromixture, as shown in equation (1).

$$C_m = \frac{m_s}{m_s + m_l} \cdot 100\% \qquad (7.1)$$

where:
C_m – mass concentration (%)
m_s – mass of the solid phase (kg)
m_l – mass of the liquid phase (kg)

Sampling of material, required for examine the mass concentration, took place by collecting and drying the three sample volumes up 100ml to obtain the average value. However, appropriate measurements of the sedimentation process using flocculant held for samples with a volume of 250 ml.

7.6 RESULTS OF RESEARCH

Figure 7.2 presents summarizes the time of sludge sedimentation for different doses of flocculant at three mixing times (tm) – 15s, 30s, 45s and the mass concentration of hydromixture C_m = 9.3%.

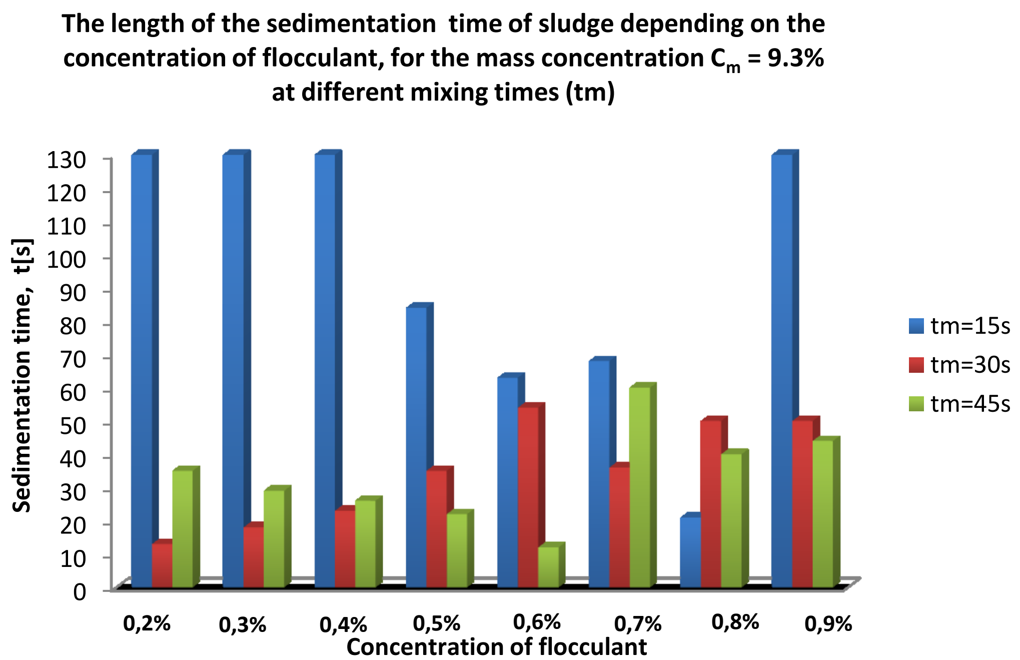

Fig. 7.2 Time dependence of sedimentation sludge from concentration of added flocculant
Source: own study

It can be seen that for the time of mixing t = 30s was obtained the fastest settling time of approx 13s, at a dose of 0.2% flocculant. For this dose of flocculant, from the beginning of the process of sedimentation, in a vessel appeared a clear separation between the liquid limit and the suspension. In measured time, counted from the time of addition the flocculant to hydromixture, the level of the suspension lowered and the sludge at the bottom grew to the point where the process of gravitational sedimentation of particles ended. In a further step, sludge was compacted obtaining the smallest porosity from observed in these conditions. For the time of sedimentation equals 13s and the flocculant mass concentration of 0.2%, the height of sediment was only 29mm.

For other flocculant concentrations above 0.2% was achieved much longer time of sedimentation and less desirable form of sedimented sludge. For example, for the higher dose of flocculant equals 0.6% and with a longer mixing time of 45s, obtained more than three times higher sediment. This height is about 72 mm, which mainly resulted from its form. The sludge was characterized by high porosity (figure 7.3).

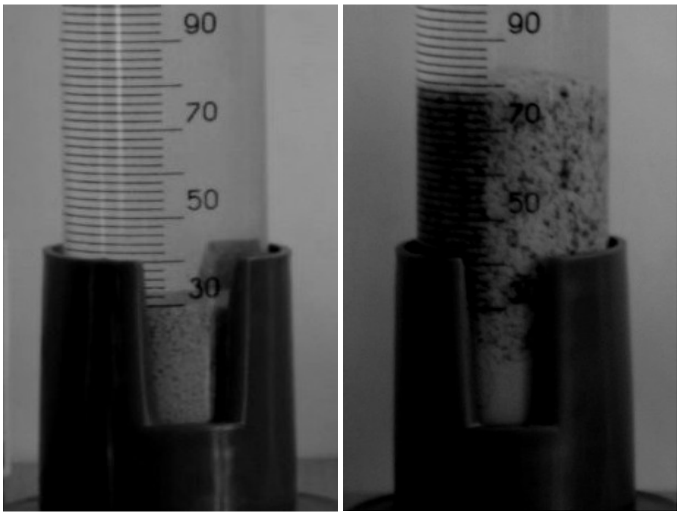

Fig. 7.3 The character of sediment after the addition of flocculant dose concentration of 0.2% (picture left) and 0.6% (picture right) to hydromixture with mass concentration C_m = 9.3%

Source: own study

Figure 7.4 shows a summary of the different doses of flocculant in one stirring time of hydromixture for the mass concentration of solid phase C_m = 9.3%.

Figure 7.4 shows the dependence of the height of sludge arisen in the sedimentation process, in function of sedimentation time, for selected concentrations of flocculant in the range from 0.2% to 1%. The presented experimental data relate to the use of constant time of stirring the samples equals 30s. As it is apparent from the figure, for solid phase concentration of C_m = 9.3% the optimum dose of flocculant is 0.2%. It results from the fact that the resulting sludge is characterized by a minimum porosity that is obtainable in these conditions, with an acceptable sedimentation time of about 13s. At higher than the optimal concentrations of flocculant, the process of sludge sedimentation in hydromixture occurs relatively quickly but the height of sludge is greater, and the consistency of sludge is porous and fluffy, because of which it occupies a larger volume.

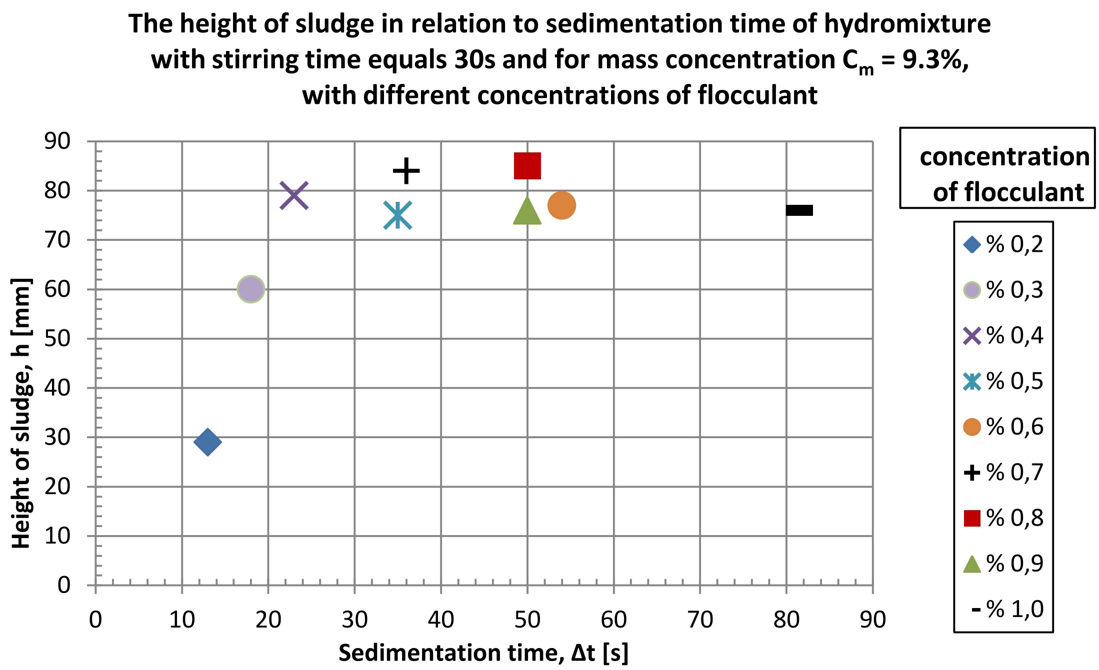

Fig. 7.4 Dependence the height of sludge in relation to the time of sedimentation at different concentrations of added dose of flocculant

Source: own study

The presented results are a part of the analysis that leads to the conclusion that the optimal dose of flocculant should be selected depending on the percentage of dry matter in hydromixture. It shows an increasing tendency connected with the growth of the mass concentration. But at higher concentrations of added flocculant than optimal, process occurs relatively quickly but leads to getting the undesirable form from the production point of view (high porosity, high hydration, a large volume of sludge).

THE RESULTS OF ANALYSIS AND SUMMARY

The use of sedimentation supported by flocculant as a method for separation the water and suspended therein fine solid phase can increase the degree of separation of solid particles in the clarification phase and obtain a sludge with possibly high content of solid in densification phase. It is estimated that as a result of spontaneous sedimentation of water in the settler tank, in normal production process of limestone without the use of flocculant, the degree of contamination of the process water is at least 0.25% of its volume. By applying flocculant, mineral slurry precipitates out from the water in greater extent and settles at the bottom of clarifier. Depending on the used flocculating agent, so purified water may characterized the degree of contamination on the level of only 0.006% its volume.

Application of installation using a flocculant for accelerating the sedimentation process in the production of limestone affects the growth of the efficiency of the recovery solid phase from hydromixture. Nearly 400m^3 of technological water characterized by high clarity is recirculated for re-use. From a technical point of view, the use of the flocculating system reduces the laborious and time-consuming of handling associated with sludge disposal. In the traditional system of waste management, select it from the settlers was very burdensome and often involve the need of manually select it from the tank. Using the presented installation whole process of water purification is automatic. Sludge formed in the process of sedimentation using flocculants is characterized by humidity less than about 8%. In addition, after extra compression it in a hydraulic press, is almost completely devoid of water so that it can be easily reloaded, transported and stored.

The average concentration of added flocculant in analyzed process maintains on the level of 0.2%. This quantity results from the percentage conversion of the added amount of flocculant in solid form in relation to dry solids content of sludge, remaining after the evaporation of water from the predetermined volume of hydromixture (2g of the powder would be added/1kg of dry weight). The amount of flocculant consumed in the process is estimated at 25 kg/day at a price of 13zł/kg. Monthly would be consumed the amount corresponding to 800 kg of the substance.

Performed experiments indicate that the use of flocculant, leading to the creation of well aggregating flocks at the bottom of the settler tank, is the right direction of change the existing technology. Carried out preliminary tests have shown that the sedimentation process can be greatly accelerated when the flocculant is pre-dissolved in water and added in a solution form to hydromixture. Tested flocculant belongs to a group of complex substances, reo-unstable, which requires more detailed tests to determine the dependence of shear stress on shear rate for the variable concentration of the solid phase in hydromixture and a variable concentration of flocculant in hydromixture.

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Abstract: *Inseparable element of the lime production process is pipeline transport of hydromixture which arises from rinsing of stones. Such hydromixture is a finely-granular solid phase and the water that serves as a carrier of the solid phase. At the end of the transporting process the water is recovered in order to recycle it for re-circulation, and the solid phase is deposited in dumps or in the sludge tanks. Hydromixture clarification process through the process of sedimentation, is difficult due to the large amount of solid particles with a diameter less than 2 μm. In order to improve the efficiency of sedimentation process we added polymer additives called flocculants. They allow the formation of flocs by binding together fine particles into larger agglomerates, which are under the influence of gravity and fall intensively to the bottom of settler tank.*
*This paper presents the results of experimental studies on the use of flocculant to accelerate sedimentation process and get back water for further use. Significant reduction of sedimentation time using the opti*mal *dose of the flocculant, which was determined in an experimental way was demonstrated.*

Key words: *hydraulic mixtures pumps, experimental studies, flocculant, efficient use of water*

POPRAWA EFEKTYWNOŚCI PROCESU PRODUKCJI WAPNA POPRZEZ ZASTOSOWANIE FLOKULANTA

Streszczenie: *Nierozłącznym elementem procesu produkcji wapna jest transport hydromieszaniny popłuczkowej. Hydromieszaninę popłuczkową stanowi drobno-ziarnista faza stała i woda służąca jako nośnik fazy stałej. Na końcu procesu transportu woda odzyskiwana jest w celu zawrócenia jej do ponownego obiegu, natomiast faza stała deponowana jest na hałdach lub w zbiornikach osadowych. Proces klarowania hydromieszaniny, poprzez proces sedymentacji, jest utrudniony ze względu na dużą ilość cząstek stałych o średnicach poniżej 2* μm*. W celu poprawy efektywności procesu sedymentacji dodawane są polimerowe dodatki zwane flokulantami. Umożliwiają one tworzenie się kłaczków (flocs) poprzez wiązanie ze sobą drobnych cząstek w większe aglomeraty, które pod wpływem grawitacji intensywnie opadają na dno osadnika.*
W artykule przedstawiono wyniki badań eksperymentalnych nad zastosowaniem flokulanta, który poprawia ekonomię efektywnego wykorzystania wody w procesie hydrotransportu i rozdział fazy stałej od fazy ciekłej. Wykazano istotne skrócenie czasu sedymentacji przy zastosowaniu optymalnej dawki flokulanta, którą określono w sposób eksperymentalny.

Słowa kluczowe: *hydromieszanina, badania eksperymentalne, flokulant, efektywne wykorzystanie wody*

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