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Stabilization of Dredged Materials Using Cement and a Pozzolanic Binder Mineral Additive

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Abstract

In this study, it was aimed to stabilize the dredged materials with low bearing capacity, brought from Edirne, by using cement and pozzolanic binder mineral additives. In the first stage of the study, the geotechnical properties of the dredging materials were determined. Then, the optimum water contents and maximum dry unit weight values of the soil samples without additives and with different additive ratios were found by compaction tests. Pure and additive unconfined compressive samples were prepared with the optimum water contents obtained in the compaction tests. Samples were prepared by adding 8%, 10% and 12% cement and 2% pozzolanic binder additive by weight to the dredged materials. Unconfined compressive tests were performed on the samples at the end of instant, 1-day, 7-day and 28-day curing periods. In addition, soaked CBR, permeability and flexural tests were performed on 12% cement+pozzolanic added samples. As a result of the experiments, with the addition of cement and pozzolanic binder additives in different ratio to the dredged materials, permeability decreased, unconfined compressive strength, soaked CBR values and flexural strength increased significantly.

1. Introduction

Dredging is generally the job of taking the material from the water environment and moving it to another location. Dredging operations are carried out to increase the depth of the open seas, inland waters, canals, shallow, polluted areas, to protect the existing water depth, to create a safe waterway, coastal protection, land reclamation, flood and erosion control. The depth of the channel or stream bed is increased by dredging works. These are excavations performed for many different purposes such as increasing the bearing capacity. A considerable amount of material is obtained as a result of dredging processes carried out on the sea floor, channels and stream beds. These materials become waste materials and their storage may cause environmental problems. Today, with the increase of environmental awareness, dredging materials are used in construction instead of being stored as waste [1-3].

Dredging materials with low bearing capacity have the opportunity to be reused by improving engineering properties with various chemical additives such as lime, cement, fly ash and bitumen. With this process, which is defined as soil stabilization, the negative properties of the weak soil are corrected, the soil becomes more stable, and the bearing capacity increases. Soil stabilization with cement is one of the most preferred methods in soil stabilization. In traditional soil stabilization methods using cement, cement alone is insufficient to react with the existing soil and can not meet the desired project criteria [4]. The use of pozzolanic, pure, binder, mineral additives together with cement in soil stabilization is one of the new methods. In this method, the powdered pozzolanic binder mineral additive allows the soil to react rapidly with the cement. In this way, a waterproof, high-strength, homogeneous and flexible ground layer with the engineering properties required by the specifications and standards is produced [5].

The pozzolanic binder material is made from 100% mineral contended alkaline and soil alkaline constituents. It

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contains natural oxides, chlorides, sulfates and carbonate minerals. Pozzolanic mineral is a white colored powder, that is non-toxic, non-detrimental for the health and environmentally friendly. It is used by adding 2% to cement and mixing with soil. Pozzolanic binder mineral combined with cement and optimal water content increases the crystallized formations during the hydration process, resulting in higher strengths, neutralizes ph levels, and provides water impermeability. The pozzolanic binder mineral neutralizes the existing acids and supports the hydration process by allowing the formation of longer crystals. Soil stabilization with pozzolanic additive can be applied on clayey, sandy, organic matter-containing soils on almost all kinds of soils. It can transform almost all kinds of soils or bases into a very strong typical 150 MN/m^2 foundation layer without replacing the existing soil in the field. The stabilized surface does not allow the penetration of the water or ice. Stabilized surface is resistant against oil, salt, acids and chemicals. Therefore, it significantly increases the physical life of the stabilized layer and does not need maintenance costs for a long time. Stabilization with cement and pozzolanic additive is applied in any type of roads, railways, storage and industrial surfaces, mines, rural roads, garbage dumping areas and airports. Cement and pozzolanic binder additive can be used as sub-base and foundation layer in road superstructures by improving the weak soils brought from off-side, in road, railway and highway constructions, and in the stabilization of infrastructure filling layers. For this purpose, it is widely used in many projects in our country [6].

Soil stabilization with cement and pozzolanic binder additive has been applied in many highway and railway projects in our country. Soil stabilization studies using cement and pozzolanic binder mineral additives were carried out in 2013 for the first time in railway projects in our country. Pozzolanic additive was used in the rehabilitation and signalization project of the Irmak-Karabük-Zonguldak railway line of the State Railways of the Republic of Turkey. Within the scope of the project, improvement was made in Çaycuma station in 2 days using the existing material on the ground, cement and pozzolanic additives, without excavating, without bringing any material from off-side. The application was applied to a clay layer with high plasticity (CH) and low strength. A homogeneous layer was obtained by using 42 kg to 62.5 kg cement and pozzolanic additive at the rate of 2% of the cement in 1 m^2 area. The soaked CBR value of the soil before the improvement was 4%. The 7-day soaked CBR value of the soil after improvement was found to be 122%. After the application, the soil layer reached a high bearing capacity in a short time. Within the scope of the State Railways of the Republic of Turkey Denizli-Afyonkarahisar Railway Line Renovation Project, weak soil layer has been stabilized by using cement and pozzolanic additive. The project was carried out on a very low strength clay layer. The soaked CBR value of this layer is about 3%. For stabilization 50 kg to 56 kg cement and a pozzolanic additive at the rate of 2% of the cement in 1 m^2 area were used. The field and laboratory tests performed in the base soil layer, which was stabilized after the production. Results were found to be quite above the values defined in the specification. Accordingly, the plate loading value, which was required to be 60 MPa in the project, was found to be 160 MPa after stabilization. Unconfined compressive tests were carried out on cement and pozzolanic added samples. The unconfined compressive strength, which is required to be at least 500 kPa in the project specification, has been determined as 1140 kPa. Cement and pozzolanic additives were used in the improvement of the filling layers in the State Railways of the Republic of Turkey Samsun-Kalın railway modernization project. Within the scope of this project, it was decided to stabilize the project with cement and pozzolanic additives, instead of rock fill, in order to complete the project more quickly. In the project, 60 kg cement per m^2 and 2%-of-the-cement pozzolanic additive were added to the low strength clay layer. It was observed that the soaked CBR values of the mixtures prepared by adding cement and pozzolanic additives were increased significantly compared to the natural material [6,7]. Kavak has determined that this stabilization method has many advantages, that this method will reduce typical road sections and provide both economic and environmental benefits. With this stabilization method, transportation costs will decrease significantly with the use of on-site material in the fillings [8].

In this study, an innovative pozzolanic binder mineral additive was used together with cement to improve the engineering properties of dredging materials with low bearing capacity, and the effects of additives on soil samples were investigated with experimental studies.

2. Materials and Methods

2.1. Cement

The cement used in the experimental studies is 32.5R pozzolanic cement, which is sold in 50 kg bags in the market. Cement complies with the conditions specified in TS EN 197-1 [9]. Standard properties are given in Table 1.

Table 1. Standard properties of cement

<table>
<tr><td rowspan="3">Strength Class</td><td colspan="4">Compressive Strength (Mpa)</td><td rowspan="3">Setting Start Time (minute)</td><td rowspan="3">Expansion (mm)</td></tr>
<tr><td colspan="2">Early Strength</td><td colspan="2">Standard Strength</td></tr>
<tr><td>2 Days</td><td>7 Days</td><td colspan="2">28 Days</td></tr>
<tr><td>32.5R</td><td>≥10.0</td><td>-</td><td>≥32.5</td><td>≤52.5</td><td>≥75</td><td>≤10.0</td></tr>
<tr><td></td><td colspan="4">TS EN 196-1</td><td colspan="2">TS EN 196-3</td></tr>
</table>

2.2. Pozzolanic Binder Mineral Additive

The pozzolanic powder binder mineral additive material used by mixing with cement in the study has 100% mineral content and consists of alkaline and earth alkaline structures. It contains natural oxides, chlorides, sulphates, and carbonate minerals. It is a white, non-toxic, environmentally friendly, natural mineral powder. The material added to the cement at the ratio of 2% is mixed with the soil [6].

2.3. Materials of Dredging

The dredging materials with low bearing capacity used in the stabilization processes were brought from a river bed from the district of Edirne. In the first stage, some experiments were carried out in order to determine the geotechnical properties of the materials brought to the Kocaeli University geotechnical laboratory and to make soil classifications. The experiments were carried out in accordance with ASTM, TS1500, TS1900-1 and TS 1900-2 standards [10-20]. Natural water content determination, organic matter determination, Atterberg consistency limits tests, wet sieve analysis, specific gravity and standard compaction tests were performed on the dredging materials, respectively. Stabilization process is applied to soil samples containing less than 4% organic matter as specified in the specification [21,22]. As a result of the organic matter determination experiments, it was determined that the organic matter content of the dredging materials was less than 4% and it was found to be 2.95%. The soil classification result and geotechnical properties are given in Table 2. It was determined that the soil class of the dredging materials is silty clayey sand (SM-SC) according to Unified Soil Classification System. As a result of the Atterberg consistency limit tests, the liquid limit value of the dredging material is 22%, the plastic limit value is 17%, and the plasticity index value is 5%. The liquid limit value was determined with the Casagrande test instrument. The specific gravity value was found by pycnometer test. The specific gravity of the dredging material was determined as 2.67. The clay + silt ratio was found to be 36.5% and the sand ratio to be 63.5% by wet sieve analysis.

Optimum water contents and maximum dry densities of the dredging materials were found by standard proctor compaction tests. The optimum water content of the dredging material was found to be 10.94%, and the maximum dry unit weight was found to be 1.74g/cm^3.The results are given in Table 2. Mixtures were formed by adding cement and pozzolanic binder mineral additives to the dredging materials whose geotechnical properties were determined.

Table 2. Properties of dredging materials

Sample	Dredging Material
Classification (USCS)	SM-SC
Liquid Limit (%)	22
Plastic Limit (%)	17
Plasticity Index (%)	5
Clay+Silt (%)	36,5
Sand (%)	63,5
Gravel (%)	0
Specific Gravity	2,67
Organic Matter (Content %)	2,95
Optimum Water Content (%w_{opt})	10,94
Maximum Dry Density (g/cm^3)	1,74

The amount of additive to be used in soil stabilization with cement and pozzolanic additives is determined by taking into account the soil class, soil CBR value, the strength required from the project, traffic load, traffic volume, field and laboratory test results. The amount of cement to be used in the study was determined according to the technical specifications of the manufacturer of pozzolanic binder material. Soil class and CBR value have great importance in the determination of the amount of cement to be used. According to this specification, the amount of cement to be used for sandy soils varies between 140-200 kg/m^3. The amount of cement to be used for laboratory tests varies between 8% and 12% of the dry unit weight of the soil. This ratio was selected to be between 8% and 12% for laboratory experiments. According to the material manufacturer, the ratio of pozzolanic additive to be used is 2% by weight of the cement amount.

Atterberg consistency limits, Harvard miniature compaction and unconfined compressive tests were carried out by adding 8%, 10% and 12% cement and pozzolanic binder mineral additive at the rate of 2% of cement to the dredging material. Permeability, soaked CBR (California Bearing Ratio) and beam flexural tests were carried out by adding 12% cement and pozzolanic binder mineral additive at the rate of 2% of cement to the dredging material. In order to obtain the highest strength ratio, experiments were carried out by choosing a single additive ratio in permeability, soaked CBR and flexural tests. Since the highest strengths were obtained at 12% additive rate as a result of unconfined compressive tests, this ratio was preferred in the tests. Atterberg consistency limit tests were applied by adding 8%, 10% and 12% cement and 2% pozzolanic binder additive to the dredging materials. The prepared mixtures were cured for 1 hour. Due to pozzolanic reactions, mixtures were cured for one hour. After curing for 1 hour, changes in the Atterberg consistency limits were observed. Harvard miniature compaction experiments were carried out by adding 8%, 10% and 12% cement and 2% pozzolanic binder additives to the dredging materials. Due to less time and materials are used, Harvard miniature compaction experiments were applied on the with additive samples. As a result of the Harvard miniature compaction tests, optimum water content and maximum dry unit weight of the mixtures were found. Unconfined compressive strength test samples were prepared with optimum moisture contents obtained by compaction tests. Cylindrical specimens were prepared using Harvard miniature compaction mold. Unconfined compressive test samples were prepared by adding cement (8%, 10%, 12%) and pozzolanic binder additive (2% of cement) to the dredging materials. Samples were prepared for instant, 1-day, 7-day and 28-day curing periods for unconfined compressive test. Three samples were prepared for each additive ratio and curing time. A total of thirty-six cement and pozzolanic added samples were prepared. Six natural samples were prepared for unconfined compressive strength tests. Three of these samples were cured for 1 day. For the others, instant tests were carried out. For comparison with cement and pozzolanic added samples, six samples with 12% cement were prepared. Three of the 12% cement samples were cured for 7 days. The others cured for 28 days. A total of forty-eight unconfined compressive samples were prepared. The samples were firstly wrapped with aluminum foil and then kept in a desiccator during the curing period. The graphs were created by taking the average of the strength values of the prepared samples. As a result of unconfined compressive tests, soaked CBR test was carried out by using 12% additive ratio, which gives the highest strength. Due to the amount of material being low, only 7- day- cured soaked CBR test was performed. The sample with 12% cement and pozzolanic added was kept in the curing room for 3 days and in water for 4 days. Falling head permeability tests were carried out to determine the permeability of the samples with and without additives. Due to the amount of material being low, only 12% cement and pozzolanic added test were carried out. The samples were prepared in the standard proctor mold at optimum water content and cured for a certain period of time. Measurements were made by saturating the samples for two weeks. Then the permeability coefficients were calculated. Finally, 40x40x160 mm prismatic samples were prepared to determine the flexural strength of the samples with additive. Due to the amount of material being low, samples with 12% cement and 12% cement + pozzolanic additives were prepared. Mixtures were prepared using optimum water contents. The mold was lubricated before the mixtures were placed in the mold. The mixtures were placed in the mold as at least 3 layers. Each layer was rammed with a plastic mallet to ensure that the mixtures were well compacted. Samples were cured for 7 and 28 days. After the samples with additive were placed in the mold, samples were kept in the curing room for 1 day. At the end of 1 day, samples were taken out of the mold and put into bags. At the end of the curing period, 3-point beam flexural tests were carried out by placing the beam in the flexural apparatus.

3. Results and Discussion

3.1. Atterberg Consistency Limits

Atterberg consistency limits tests were conducted by adding 8%, 10% and 12% cement and pozzolanic binder additive at the rate of 2% to the dredging materials. Changes in the Atterberg consistency limits were observed after curing for a certain period of time. As a result of the experiments, it was determined that the plastic limits of the samples increased, and the plasticity indices decreased as the additive ratios increased. With the addition of 8% cement and pozzolanic binder mineral additives to the dredging materials, the liquid limit value of the dredging materials was 24.55%. Plastic limit values increased to 21.22%. The plasticity index of the dredging materials decreased to 3.33%. With the addition of cement (C) and pozzolanic additives (PA), the workability of the dredging materials increased. The changes in the Atterberg consistency limits with the addition of additives in different ratios to the dredging materials are shown on the graphic in Figure 1.

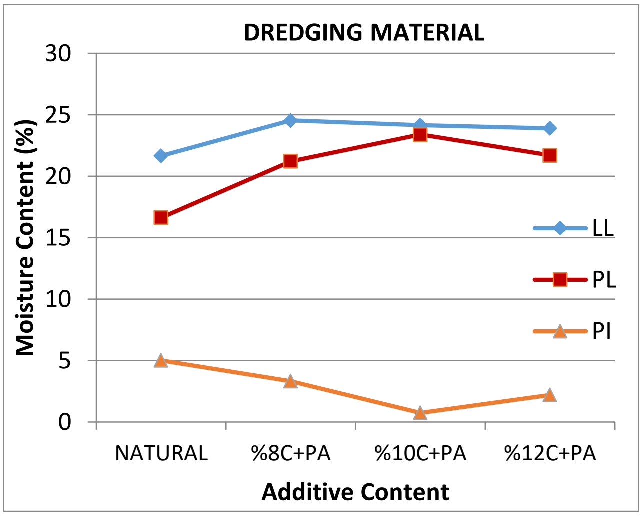

Figure 1. The Atterberg consistency limits of the dredging material with different additive ratios.

3.2. Harvard Miniature Compaction

Harvard miniature compaction experiments were carried out by adding 8%, 10% and 12% cement and 2% pozzolanic binder additives to the dredging materials by weight. As a result of the compaction tests, optimum water content and maximum dry unit volume weight of the mixtures were determined. In all the with additive samples, the optimum water content increased compared to the natural state. The maximum dry densities of the with-additive dredging materials increased compared to the natural state. The Harvard miniature compaction test results of the samples with additives are given in Table 3.

Table 3. Harvard Miniature compaction test results

Mixtures	Optimum Moisture Content (%W_{opt})	Maximum Dry Density (g/cm^3)
(SM-SC)+%8C+PA	14,48	1,79
(SM-SC)+%10C+PA	14,76	1,78
(SM-SC)+%12C+PA	13,93	1,80

3.3. Permeability

In this study, the permeability of dredging materials and with additive samples was found by decreasing level permeability tests. The permeability coefficients were found by adding 12% cement and with pozzolanic binder mineral additive at the ratio of 2% to the dredging materials. The impermeability degrees of the samples were determined by comparing the permeability coefficients of the samples with and without additives. For this purpose, additive and non-additive mixtures have been formed by using the optimum water contents obtained in compaction experiments. The resulting mixtures were compressed with standard proctor energy in a standard compaction mold at optimum water contents. The prepared samples with additives were cured for a certain period of time. Then, the compressed and cured samples with and without additives were placed in the falling head permeability mechanism and the samples were waited until they became saturated. The samples were allowed to become saturated for about a two week. Later, falling-head permeability experiments were carried out, and readings of the falling water level were made periodically. Permeability coefficients were calculated with the data obtained. At the end of the study, it was calculated that the permeability coefficients of the non-additive samples were greater than the permeability coefficients of the samples with 12% cement + pozzolanic additive.

It was observed that the permeability of the with additive samples decreased as the permeability coefficients decreased. According to Terzaghi and Peck's (1967) soil permeability coefficient classification, it was concluded that samples with additives can be considered practically impermeable. Table 4 gives Terzaghi and Peck's (1967) classification of soils according to their permeability coefficients [23]. In Table 5, the permeability coefficients of the without- additive and with- additive samples are shared. The permeability of the dredging material decreased with the addition of cement (C) and pozzolanic additives. Dredging materials have become impermeable. As a result of impermeability, water does not enter the soil, so the soil does not freeze. As a result, the soil is resistant to salt, acids and chemicals.

Table 4. Coefficient of permeability (Terzaghi and Peck)

Degree of Permeability	Coefficient of Permeability, k (cm/s)
High	Over 10^{-1}
Medium	10^{-1}-10^{-3}
Low	10^{-3}-10^{-5}
Very Low	10^{-5}-10^{-7}
Practically Impermeable	Less Than 10^{-7}

Table 5. Permeability coefficients of the specimens

Specimens	**Coefficient of Permeability, k (cm/s)**
Natural Soil (SM-SC)	5,13x10^{-7}
Natural Soil+%12C+PA	9,84x10^{-9}

3.4. Soaked CBR (California Bearing Ratio)

The soaked CBR (California Bearing Ratio) test is used to determine the bearing strength of soils. In the scope of the study, soaked California Bearing Ratio (CBR) tests were carried out in accordance with TS EN 1900-2 specification by using the optimum water contents obtained by compaction tests. Firstly, the soaked CBR values of natural samples were found. Then, 12% cement and 2% pozzolanic binder mineral additives were added to the dredging material and the mixtures were prepared. All samples prepared were kept in water for four days. The samples with additives were placed in the curing room before being kept in water and cured for a certain period of time, and soaked CBR tests were applied at the end of seven days. The soaked CBR values of the natural samples were determined as 2.5%. The soaked CBR values of the 12% cement and pozzolanic added dredging materials were found to be 120%. The soaked CBR value of the dredging materials with cement + pozzolanic additives at the end of the seven-day curing period has increased forty-seven times compared to the natural state. The seven-day soaked CBR values of the stabilized dredging materials increased significantly compared to the natural state, and the dredging materials with low bearing capacity became usable in construction. In Figure 2, the soaked CBR (California Bearing Ratio) values of the additive and non-additive samples are graphically given.

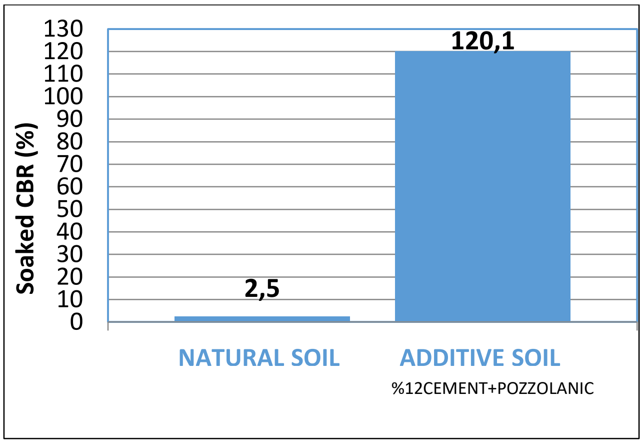

Figure 2. Soaked CBR values

3.5. Unconfined Compressive Strength

Unconfined compressive strength test samples were prepared with optimum moisture contents obtained by compaction tests. Firstly, samples with instant and 1 day curing time were prepared using optimum water contents without additive to the dredging material. The average unconfined compressive strength value of the dredging material was found to be 23 kPa for instant. The average of unconfined compressive strength value of the 1 day cured samples was determined as 40 kPa. Then, instant, 1-day, 7-day and 28-day unconfined compressive samples were prepared by adding 8%, 10% and 12% cement and 2% pozzolanic binder additives to the dredging materials by weight. At the end of the curing period, the unconfined compressive strengths were determined. The average of unconfined compressive strength of dredging materials with 8% cement and pozzolanic binder mineral additive were found as 313 kPa, 870 kPa, 1517 kPa, 2130 kPa for instant, 1 day, 7 days and 28 days curing times, respectively. The average unconfined compressive strength values of samples with 10% cement and pozzolanic additives were found as 330 kPa, 985 kPa, 1700 kPa, 2460 kPa for instant, 1 day, 7 days and 28 days curing times, respectively. In the samples with 12% cement + pozzolanic additives, the average unconfined compressive strengths were found as 390 kPa, 1090 kPa, 1720 kPa and 2600 kPa for instant tests, after 1 day, after 7 days and after 28 days respectively. In addition, 12% by weight of cement was added to the dredging materials and strength test samples were prepared for 7-day and 28-day curing times and their compressive strength was compared with the cement + pozzolanic binder added samples. According to the compressive test results, the 7-day unconfined compressive strength of the dredging material with 12% cement additive was found to be 1500 kPa, and the 28-day strength was found as 1660 kPa. The unconfined compressive strength values of the dredging materials without additives and with cement + pozzolanic additives in different ratios are given in Figure3

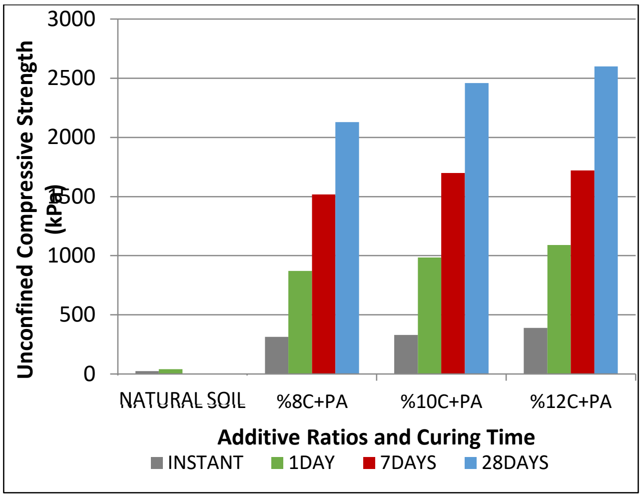

Figure 3. Unconfined compressive strengths

Figure 3 shows the without-additive and with-additive unconfined compressive strength values of the dredging materials. The highest strength in the samples with additives was obtained with 12% cement + pozzolanic binder mineral additive added to the dredging material. 12% cement and pozzolanic additive were added to the dredging material, and the unconfined compressive strength of over 2.5Mpa was obtained at the end of the 28-day curing period. It was also observed that their strength is considerably lower than pozzolanic additive ones. Figure 4 shows the unconfined compressive strength graphs formed by adding 12% cement to the dredging materials.

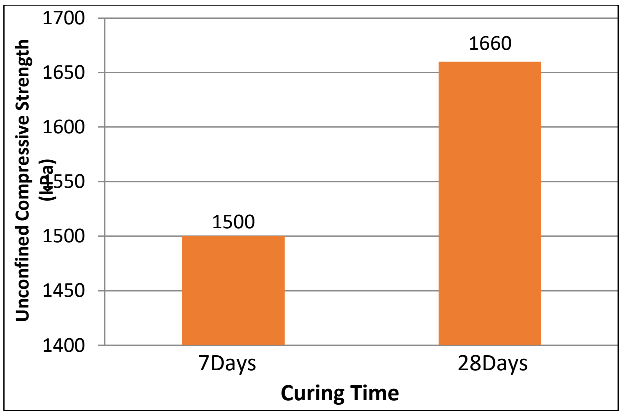

Figure 4. Unconfined compressive strength with 12% cement added

Figure 5 shows the stress unit deformation graph that occurs at the end of the twenty-eight day curing period when cement and pozzolanic additives are added to the dredging materials in different ratios. In Figure 6, the natural and different ratios of cement + pozzolanic additive instant samples stress-strain graphs for the dredging materials are given. The unit deformation of samples decreased as the amount of additive materials increased. The unit deformation of samples decreased as the curing period of samples increased.

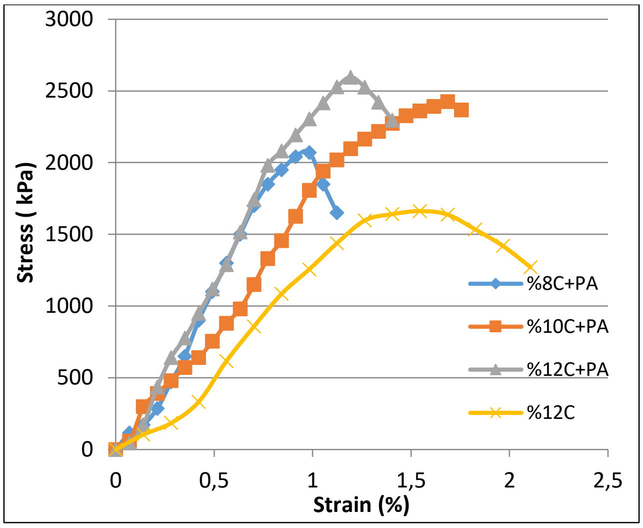

Figure 5. Stress-strain curves of 28 day cured samples

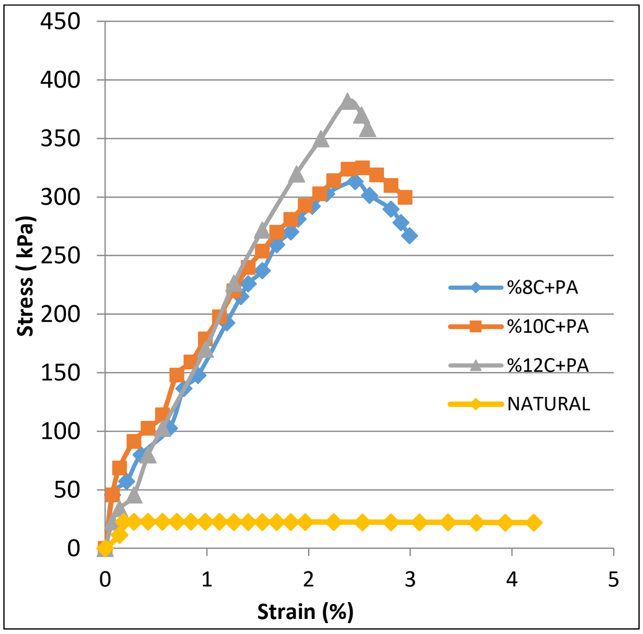

Figure 6. Stress-strain curves of instant samples

3.6. Flexural Strength

In the study, 40x40x160 mm prismatic samples were prepared in order to determine the flexural strength of the with- additive dredging materials. The samples were prepared by adding 12% cement and 12% cement + pozzolanic additives to the dredging materials. The prepared samples with additives were kept in the curing room for 7 days and 28 days, then 3-point flexural tests were conducted using the beam flexural apparatus. According to the test results, it was seen that the cement + pozzolanic added samples have higher flexural strength than the cement-added samples. The flexural strength results are given in Figure 7 and Figure 8. According to the flexural strength test results, it was determined that the cement + pozzolanic binder mineral added samples were more flexible than the cement-added samples.

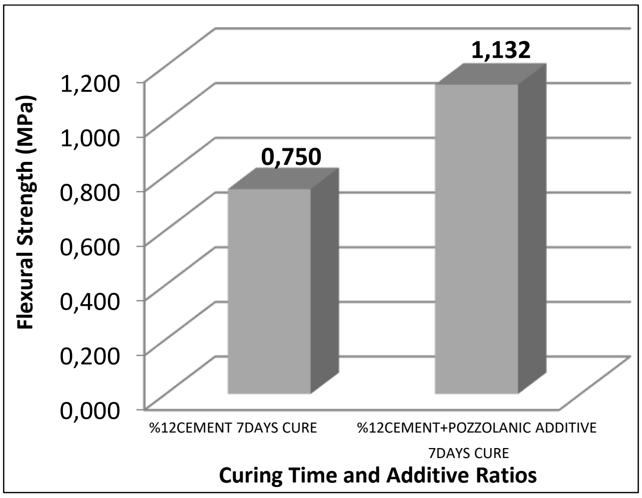

Figure 7. Flexural strengths for 7 days curing time

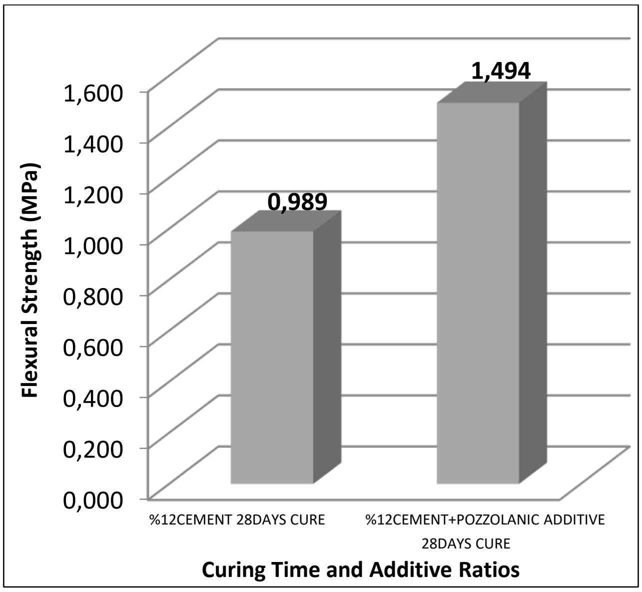

Figure 8. Flexural strengths for 28 days curing time

4. Conclusions

In this study, an innovative pozzolanic binder mineral additive was used together with cement to improve the engineering properties of dredging materials with low bearing capacity, and the effects of additives on soil samples were investigated with experimental studies. Unconfined pressure tests were carried out by adding cement (8%, 10%, 12%) and pozzolanic binder additive (2% cement) to the dredging materials. The unconfined compressive strength of dredging materials significantly increased with the amount of cement and pozzolanic additive.The unconfined compressive strengths of dredging materials increased with curing time increase. In the study, it was determined that the strength of the cement + pozzolanic-added dredging materials was higher than the cement-added materials.

With the addition of cement and pozzolanic binder additives to the dredging materials, the plastic limits increased, and the plasticity indices decreased. This shows that the dredging materials turn rigid with the addition of cement + pozzolanic additive and their workability increases.

With the increase in the rate of additives and curing time added to the dredging materials, there has been a serious increase in their strength. Increases were observed in the unconfined compressive strengths of the dredging materials with 12% cement + pozzolanic binder additive, with a curing time of 28 days compared to the dredging materials in natural state.

The soaked CBR values of the dredging material with 12% cement + pozzolanic binder with 7 days curing time has increased approximately 48 times compared to the natural state. The soaked CBR values for stabilized materials increased from 2.5% to 120.1%. The high CBR values obtained, by reducing the thickness of the road layer in road constructions, enable more economical and low-cost roads.

Mixtures formed by adding 12% cement + pozzolanic binder additive to the dredging materials were subjected to permeability tests and their permeability coefficients were calculated and permeability degrees were determined. Dredging materials have become impermeable. In this way, dredging materials is more resistant to acids, salts and chemicals.

As a result of the flexural strength tests, it was determined that the flexural strength of the cement + pozzolanic additive dredging materials was higher than the only cement-added samples. The stabilized material becomes more flexible through the addition of pozzolanic additives compared to the traditional stabilization made with cement. This has enabled the disadvantages of the extremely rigid structure seen in the stabilization with cement to be eliminated. The high flexural strengths show that the cement + pozzolanic binder-added soil has become more flexible and more resistant to fractures.

Through the stabilization process with cement + pozzolanic binder additive, the dredging materials with low bearing capacity, taken from the field, can be used as filling, sub-base and base material in construction sites. In this way, instead of being stored as waste, it is used in constructions and the damage to the environment can be prevented.

As a result, in this study, considering high strength, high elasticity and impermeability, it was revealed that stabilization with cement and pozzolanic additives is much more effective than traditional soil stabilization with cement in the stabilization of low bearing capacity dredging materials.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and legal-special permission.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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