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Freeze-Thaw Resistance of Fine-Grained Soils Stabilized with Waste Material Mixtures

Necmi Yarbaşı
Department of Civil Engineering
Engineering Faculty
Ataturk University
Erzurum, Turkey

Ekrem Kalkan
Department of Civil Engineering
Engineering Faculty
Ataturk University
Erzurum, Turkey

Abstract: This paper evaluates the use of waste material mixtures including marble dust and scrap tire rubber the stabilization of fine-grained soils in order to remove the effects of freeze-thaw cycles. In this study, a fine-grained soil material was stabilized by using waste material mixtures. Natural and stabilized fine-grained soil samples were subjected to freeze-thaw cycles under different curing periods. After the freeze-thaw cycles, compressive strength tests were performed to investigate effects of waste material mixtures on the freeze-thaw resistance of fine-grained soil samples. The experimental results showed that the samples of fine-grained soil stabilized with waste material mixtures have high freeze-thaw durability as compared to unstabilized fine-grained soil samples. Consequently, we conclude that waste material mixtures including marble dust and scrap tire rubber, can be successfully used as an additive material to enhance the freeze-thaw durability of fine-grained soils for soil stabilization in the geotechnical applications.

Keywords: Fin-grained soil; soil stabilization; freeze-thaw; marble dust; scrap tire rubber

1. INTRODUCTION

Fine-grained soil (FGS) is generally classified as expansive soil. This means that some clays will tend to expand as they absorb water and will shrink as water is drawn away. These FGSs contain clay minerals that have the potential for swelling and shrinkage under changing moisture contents. Clay minerals could originate from the weathering of shale, slate, sandstone, and limestone. Another source is the diversification of volcanic ash deposited under marine conditions during geologic times, settled alone or mixed with shale or limestone (Grim 1968; Kalkan and Bayraktutan, 2008). Expansive soils are known to cause severe damage to structures resting on them. However, these soils are very important in geology, construction, and for environmental applications, due to their wide usage as impermeable and containment barriers in landfill areas and other environmentally related applications (Erguler and Ulusay, 2003; Harvey and Murray, 1997; Kayabali, 1997; Keith and Murray 1994; Murray, 2000; Sabtan, 2005). Safe and economic designs of foundations on FGSs and performance of compacted clayey soils for geotechnical purposes require the knowledge of swelling characteristics such as swelling pressure, swelling potential and swelling index. Cyclic drying and wetting phenomena can cause progressive deformation of expansive clayey soils, which may affect building foundations, drainage channels, buffers in radioactive waste disposals, etc. (Guney et al., 2007; Nowamooz and Masrouri, 2008; Rao et al., 2001).

Construction of buildings and other civil engineering structures on weak or soft soil is highly risky because such soil is susceptible to differential settlements due to its poor shear strength and high compressibility. Expansive clays are dominated by clay minerals with the potential for crystalline swelling, such as minerals of the smectite group. These are recognized as having very small particles, even among the clay minerals (Meunier, 2006; Fityus and Buzzi, 2009). Expansive soils are highly plastic that typically contain clay minerals such as montmorillonite that attract and absorb water. If clayey soils contain montmorillonite or a certain type illite, they will have significant swelling potential when wetted and tend to influence their engineering behavior (Shi et al. 2002; Sabtan 2005). Reaction of an expansive soil to changed environmental conditions is to swell or exert large pressures against non-yielding structures; but it may also exhibit a high degree of shrink-swell reversibility with changes in moisture content, leading to deformation and damage to buildings (Popescu 1979; Mohan et al. 1973; Mitchell 1993; Bell and Maud 1995; Du et al. 1999; Abdullah and Al-Abadi, 2010; Kalkan, 2012; Kalkan and Yarbaşı, 2013; Mohamedgread et al., 2019; Yarbaşı and Kalkan, 2020).

In cold regions, soils in areas with seasonal frost are exposed to at least one freeze-thaw cycle every year. In the freezing period, subsoil moisture moves towards the frozen layer because of a temperature gradient. Void spaces of soil gradually increase due to frost heave and moisture moves to the interstices of the soil and then freezes. In the thawing period, thawing of the frozen layer begins from the top and the bottom at the same time. The maximum soil moisture content appears above frozen layer and becomes temporarily-perched water. Additionally, the soil moisture content under frozen layer is more than it was during the prefrozen period (Zhang and Shijie, 2001; Yarbaşı et al., 2007).

Nowadays there are various alternatives available to increase the strength and stiffness of the weak soil and to improve the behavior of soil under various loading and environmental conditions (Parihar et al., 2015). Many earth structures such as liners of waste landfills, levees and dams are constructed of FGSs. Also, excavated FGSs might be reused as fill material in some earth structures. In these kinds of applications, there could be a tendency for characteristics of the soils (e.g. strength, volume change and mechanical characteristics) to vary over time. One possible solution to these problems is the use of randomly distributed tensile reinforcement elements in the soil. Such elements are available as polypropylene fibers (Yetimoğlu et al., 2005; Akbulut et al., 2007; Zaimoğlu, 2010; Zaimoğlu and Yetimoğlu, 2012; Yarbaşı and Kalkan, 2020).

Several stabilization methods are available for stabilizing expansive soils. These methods include stabilization with chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods (Chen, 1988; Nelson and Miller, 1992). All these methods may have the disadvantages of being ineffective and expensive. Therefore, new methods are still being researched to increase the strength properties and to reduce the swell behaviors of expansive soils (Puppala and Musenda, 2002). Many investigators have experienced on natural, fabricated, and by-product materials to use them as stabilizers for the modification of clayey soils (Aitcin et al., 1984; Sandra and Jeffrey, 1992; Kayabali, 1997; Asavasipit et al., 2001; Prabakar et al., 2003; Kalkan and Akbulut, 2004; Cetin et al., 2006; Kalkan, 2006; Akbulut et al., 2007; Kalkan, 2020; Kalkan et al., 2020; Yarbaşı and Kalkan, 2020).

The waste of marble dust (MD) can cause environmental problem and economic loss if the waste is not used. Leaving the waste material to the environment directly can cause environmental problems. Therefore, many countries have still been working on how to reuse the waste material so that they give fewer hazards to the environment. The MD is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health.

Therefore, utilization of the MD in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment (Karasahin and Terzi, 2007). Wastes can be used to produce new products or can be used as admixtures so that natural sources are used more efficiently and the environment is protected from waste deposits. The MD is generally used as reinforcement material or raw material in various areas and applications (Davini, 2000; Arslan et al., 2005; Acchar et al., 2006; Akbulut and Gurer, 2007; Karasahin ve Terzi, 2007; Saboya et al., 2007; Hwang et al., 2008; Pereira et al., 2008; Aruntas et al., 2010; Celik and Sabah, 2008; Demirel, 2010).

The concept of soil reinforcement with natural fiber materials originated in ancient times. Randomly distributed fiber-reinforced soils have recently attracted increasing attention in geotechnical engineering (Yetimoglu and Salbas, 2003). The concept and principle of soil reinforcement was first developed by Vidal (1969). He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the medium. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity, and reduce settlements and lateral deformation. There are several researches investigating the utilizability of scrap tire rubber as low-cost additive material for the soil stabilization (Hausmann, 1990; Prabakar and Sridhar, 2002; Yarbaşı et al., 2007; Akbulut et al., 2007; Zaimoğlu, 2010; Zaimoğlu and Yetimoğlu, 2012; Kalkan, 2013; Yarbaşı and Kalkan, 2020).

The main objectives of this research are to investigate the utilizability of waste material mixtures including MD and scrap tire rubber (STR) for stabilization of FGSs in geotechnical applications. Also, to test the strength performance of FGSs stabilized with waste material mixtures. To accomplish these objectives, natural FGS samples were stabilized by using different contents of waste material mixtures. The stabilized FGSs obtained by the compaction process were subjected the unconfined compression tests after exposing the freeze-thaw cycles and the results obtained were compared with that of natural FGSs.

2. EXPERIMENTAL MATERIALS

2.1. FGS

The FGS used in this experimental study was supplied from the clay deposits of Oltu Oligocene sedimentary basin, Erzurum, NE Turkey. This soil with green color and high plasticity is over-consolidated and it has clayey-rock characteristics in natural conditions. It is defined as a high plasticity soil (CH) according to the Unified Soil Classification System (Kalkan, 2003; Kalkan and Akbulut, 2004; Kalkan and Bayraktutan 2008). The chemical composition and engineering properties of the FGS are summarized Tables 1, and 2, respectively.

Table 1. Chemical properties of FGS and MD

Components	FGS	MD
SiO_2	46.83	0.36
Al_2O_3	15.35	0.28
Fe_2O_3	6.81	0.04
CaO	11.02	54.98
MgO	4.52	0.62
Na_2O_3	0.92	0.03
K_2O	1.23	0.07
TiO_2	0.81	-
SO_3	-	0.06
CaO_2	-	43.56

Table 2. Some properties of FGS and MD

Properties	FGS	MD
Density, g cm^{-3}	2.63	2.75
Sand (%)	2	-
Silty (%)	66	-
Clay (%)	32	-
Liquid limit (L_L, %)	73	-
Plastic limit (P_L, %)	35	-
Unit volume weight (g/cm^3)	37	-
Porosity (%)	-	0.2

2.2. MD

The waste MD was obtained in wet form as an industrial by-product directly from the deposits of marble factories, which forms during the sawing, shaping and polishing processes of marble in Afyon (Turkey) region. The wet marble sludge was dried up prior to the preparation of the samples. The dried material was sieved through a 0.25 mm sieve to remove the coarse particle (Kalkan and Yarbaşı, 2013). Ths generally used as reinforcement material or raw material in various areas and applications. The chemical composition and physical properties of MD are given in Tables 1 and 2, respectively.

2.3. STR

The STR fibers were supplied by local recapping truck tires producer in Erzurum, Northeast Turkey. When the tread on truck tires down, it is more economical to stave off the old tread and replace it than to purchase brand new tires. The tire is shaved off into 150 mm and smaller strips using a sharp rotating disc. These strips are then ground into scrap rubber (Pierce and Blackwell, 2003; Akbulut et al., 2007). The STR fibers used in this study has length of 1.18 mm. The engineering properties of the STR fiber were given in the Table 3.

3. EXPERIMENTAL PROSEDURE

3.1. Preparation of sample mixtures

The FGS used in this study was dried in an oven at approximately 65 °C and then ground before the preparation of mixtures. The required amounts of FGS, MD and STR were prepared and then blended together under dry conditions. As the waste STR fibers tended to lump together, considerable care and time were spent to get a homogeneous distribution of the waste STR fibers in the mixtures. The weights of the mixtures were determined according to the formula below;

$$W_{MIX} = W_{FGS} + W_{MD} + W_{STR} \quad (1)$$

where W_{MIX}, W_{FGS}, W_{MD}, W_{STR} are the total dry weights of sample mixtures, FGS, MD and STR, respectively. The component of the samples used in the experimental studies is summarized in Table 4.

Table 3. Some properties of FGS and MD

Parameters	Value
Density (mg/cm^3)	1.153-1.189
Elastic modulus (MPa)	1.97-22.96
Tensile strength (MPa)	28.1
Extent at failure (%)	44-55
Softening temperature (°C)	175

Table 4. Some properties of FGS and MD

No	Sample	Materials (%)			Total (%)
		CS	MD	STR	
1	MIX1	100.00	-	-	100
2	MIX2	94.5	5	0.5	100

3.2. Compaction tests

To prepare the samples for unconfined compression tests, Standard Proctor tests were performed in accordance with ASTM D 698. Each material was evaluated at six different water concentrations in three steps. To ensure uniform compaction, the required quantities of FGS-waste material mixtures were placed inside mold-collars assemblies and compressed alternately in three steps from the two ends until the samples reached the dimensions of the mold.

3.3. Unconfined compression tests

The unconfined compressive strength (UCS) values of natural FGS and stabilized FGS samples were determined from the unconfined compressive tests in accordance with ASTMD 2166. This test is widely used as a quick and economical method of obtaining the approximate compressive strength of the cohesive soils. In this study, three cylindrical samples were prepared and tested for each combination of mixtures. The unconfined compressive tests were performed at a deformation rate of 0.16 mm/min.

3.4. Freeze-thaw tests

The freeze-thaw tests were performed by a programmable freezing apparatus. The natural and stabilized FGS samples were subjected to freeze-thaw tests in accordance with ASTM C 666. All samples were placed in the freezing apparatus and conditioned at −18 °C for 2.30 h. During the freezing process, the cylindrical samples were insulated by 50 mm polystyrene to obtain one-dimensional freezing. After the freezing was completed, the samples were transferred from the freezing apparatus into a test room at +20 °C for 2.30 h. This freeze-thaw cycle was repeated 20 times and then these samples were subjected to the unconfined compression tests.

4. RESULTS AND DISCUSSION

4.1. Effect of mixtures on the UCS

The effect of waste material mixtures on the UCS values of the FGS was obtained by performing the unconfined compression tests under laboratory condition. The natural and waste material mixture-stabilized FGS samples were cured for 1, 7 and 28 days and then all samples were subjected to the tests at the end of curing periods. The test results showed that the waste material mixtures improved the UCS values of FGS samples. The increase in the UCS value of stabilized FGS with waste material mixtures was obtained at each different combination (Figure 1). However, the maximum values of the UCS was observed at the stabilized samples with waste material mixtures including 5% MD and 0.5% STR wastes. Less and more from optimum content of MD and STR caused the decrease in the UCS values of stabilized FGS.

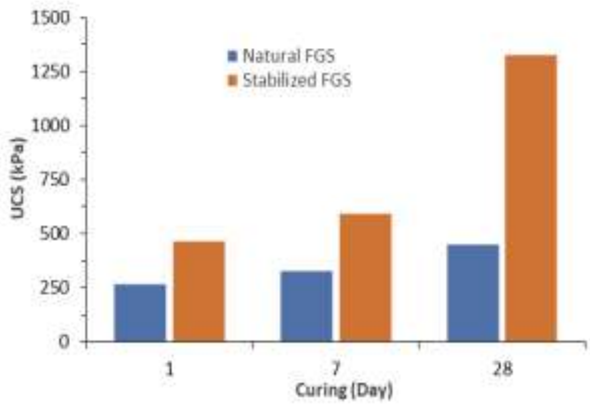

Figure 1. The effects of waste material mixtures on the UCS

The curing time played an important role on the increase of UCS values for stabilized FGS samples when compared that of fresh stabilized FGS samples. It was seen that with the increase in the curing time, UCS values of stabilized FGS samples also increased and maximum UCS values obtained at the 28-day curing time (Fig. 1). The same results were obtained from some experimental studies carried out in the past (Ranjan et. al., 1996; Prabakar and Sridhar, 2002; Akbulut et al., 2007; Zaimoglu, 2010; Hejazi et al., 2012; Kalkan, 2013; Muntohar et al., 2013; Lv and Zhou, 2019; Benziane et al., 2019).

Both the MD and STR contents play an important role in the development of UCS of stabilized FGS. The results indicate that MD-STR mixtures have more effect on the UCS than that of the MD or the STR. The improve in the UCS values of stabilized FGS samples was attributed to the changes in the composition of material mass. The addition of waste material mixtures including MD and STR wastes caused the change in the composition of stabilized FGS. It was noted in literature that the addition of additive changed the composition, mineralogy and particle size distribution of clayey soil (Gillot, 1968; Ola, 1978; Kalkan and Akbulut, 2004).

Similarly, the STR fiber played an important role in the increase in the UCS values of stabilized FGS. The increase in the UCS might be due to the bridge effect of fiber which can efficiently impede the further development of failure planes and deformations of the soil (Maher and Ho, 1994; Tang et al., 2007; Zaimoğlu and Yetimoğlu, 2012).

4.2. Effect of mixtures on the freeze-thaw resistance

The effects of waste material mixtures on the freeze-thaw resistance of FGS samples were investigated under laboratory conditions. The results obtained from the experimental studies showed that the waste material mixtures including MD and STR wastes increased the UCS values of stabilized FGS. As compared to the unstabilized FGS samples before freeze-thaw cycles, the UCS value of the stabilized FGS sample contents of 5% MD and 0.5% STR wastes and at 28-day curing period was the maximum level. It can also be seen that the stabilized FGS with the MD and STR wastes exhibit more ductile behavior than the unstabilized FGS samples. Similar results were also obtained for granular soils modified with waste additives (Akbulut et al., 2007; Yarbasi et al., 2007; Zaimoğlu, 2010; Kalkan, 2013).

The UCS values of all samples were decreased after freeze-thaw cycles (Figure 2). It may be attributed to the fact that pore water freezes and forms ice lenses in the pore space between the soil particles; then these ice lenses expand in volume and push particles of the soil and act like springs, increasing gaps among soil particles (Tunç, 2002; Isik et al., 2020). However, the decrease in the UCS values of stabilized FGS samples were lower level than that of unstabilized FGS samples after freeze-thaw cycles (Figure 3). The more UCS values of stabilized samples brought the more freeze-thaw resistance against to the freeze-thaw cycles (Yarbaşı and Kalkan, 2019).

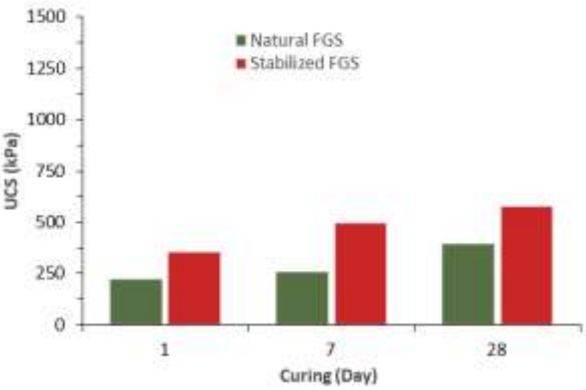

Figure 2. The effects of waste material mixtures on the freeze-thaw cycles

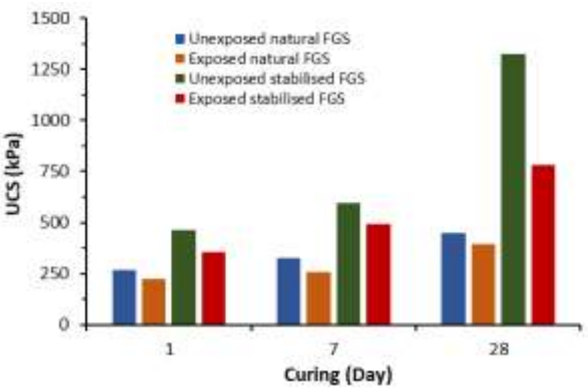

Figure 3. Effects of waste material mixtures on the freeze-thaw cycles

5. CONCLUSIONS

In this study, the effect of waste material mixtures including MD and STR wastes on the strength behavior of stabilized FGS samples was investigated and some conclusions were drawn. It was seen from experimental results that the addition of waste material mixtures increases in the UCS values of stabilized FGS samples. Meanwhile, the stabilized FGS samples were had more freeze-thaw resistance when compared with that of unstabilized FGS samples. It was concluded that waste material mixtures including MD and STR wastes can be used to improve the strength properties of FGS. In addition, this mixture can potentially reduce stabilization costs by utilizing wastes in a cost-effective manner.

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7. REFERENCES

[1] Abdullah, W.S., Al-Abadi, A.M., 2010. Cationic-electrokinetic improvement of an expansive soil. Applied Clay Science 47, 343-350.

[2] Acchar, W., Vieira, F.A., Hotza, D., 2006. Effect of marble and granite sludge in clay materials. Materials Science and Engineering: A 419, 306.9.

[3] Aitcin, P. C., Ballivy, G., Parizeau, R., 1984. The use of condensed silica fume in grouting. Innovative Cement Grouting. Publication SP-83, ACI Detroit MI, USA, 1-18.

[4] Akbulut, S., Arasan, S., Kalkan, E., 2007. Modification of clayey soils using scrap tire rubber and synthetic fibers. Applied Clay Science 38, 23-32.

[5] Akbulut, H., Gurer, C., 2007. Use of aggregates produced from marble quarry waste inasphalt pavements. Build Environ 42, 1921-1930.

[6] Arslan, E.I., Aslan, S., Ipek, U., Altun, S., Yazıcıoglu, S., 2005. Physico-chemical treatment of marble processing wastewater and the recycling of its sludge. Waste Management and Research 23, 550-559.

[7] Aruntas, H.Y., Guru, M., Dayi, M., Tekin, I., 2010. Utilization of waste marble dust as an additive in cement production. Materials and Design 31, 4039-4042.

[8] Asavasipit, S., Nanthamontry, W., Polprasert, C., 2001. Influence of condensed silica fume on the properties of cement based solidified wastes. Cement and Concrete Research 31, 1147-1152.

[9] Bell, F.G., Maud, R.R., 1995. Expansive clays and construction, especially of low-rise structures: A viewpoint from Natal, South Africa. Environmental and Engineering Geoscience 1 (1), 41-59.

[10] Benziane, M.M., Della, N., Denine, S., Sert, S., Nouri, S., 2019. Effect of randomly distributed polypropylene fiber reinforcement on the shear behavior of sandy soil. Studia Geotechnica et Mechanica 41 (3) , 1-9.

[11] Celik, M.Y. Sabah, E., 2008. Geological and technical characterization of Iscehisar (Afyon-Turkey) marble

deposits and the impact of marble waste on environmental pollution. Journal of Environmental Management 87, 106-116.

[12] Cetin, H., Fener, M., Gunaydin, O., 2006. Geotechnical properties of tire-cohesive clayey soil mixtures as a fill material. Engineering Geology 88 (1-2), 110-120.

[13] Chen, F.H., 1988. Foundations on Expansive Soils. Elsevier Scientific Publishing co., Amsterdam.

[14] Davini, P., 2000. Investigation into the desulphurization properties of by-products of the manufacture of white marbles of Northern Tuscany. Fuel 79, 1363-1369.

[15] Demirel, B., 2010. The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete. International Journal of the Physical Sciences 5 (9), 1372-1380.

[16] Du, YL., Li, S.L., Hayashi, S., 1999. Swelling-shrinkage properties and soil improvement of compacted expansive soil, Ning-Liang Highway, China. Engineering Geology, 53, 351-358.

[17] Erguler, Z.A., Ulusay, R., 2003. A simple test and predictive models for assessing swell potential of Ankara (Turkey) Clay. Engineering Geology 67, 331-352.

[18] Fityus, S., Buzzi, O., 2009. The place of expansive clays in the framework of unsaturated soil mechanics. Applied Clay Science 43, 150-155.

[19] Gillot, J.E., 1968. Clay in Engineering Geology. Elsevier, New York.

[20] Grim, R.E., 1968. Clay Mineralogy. McGraw Hill, New York. p 596.

[21] Guney, Y., Sari, D., Cetin, M., Tuncan, M., 2007. Impact of cyclic wetting-drying on swelling behavior of lime-stabilized soil. Building and Environment 42, 681-688.

[22] Harvey, C.C., Murray, H.H., 1997. Industrial clays in the 21st century: a perspective of exploration, technology and utilization. Applied Clay Science 11, 285-310.

[23] Hausmann, M.R., 1990. Engineering Principles of Ground Modification. McGraw-Hill, New York.

[24] Hejazi, S.H., Sheikhzadeh, M., Abtahi, S.M., Zadhoush, A., 2012. A simple review of soil reinforcement by using natural and synthetic fibers. Construction and Building Materials 30, 100-116.

[25] Hwang, E.H., Ko, Y.S., Jeon, J.K., 2008. Effect of polymer cement modifiers on mechanical and physical properties of polymer-modified mortar using recycled artificial marble waste fine aggregate. Journal of Industrial and Engineering Chemistry 14, 265-271.

[26] Isik, F., Akbulut, K.R., Zaimoglu, A.S., 2020. Influence of Waste Toothbrush Fiber on Strength and Freezing–Thawing Behavior in High Plasticity Clay. Studia Geotechnica et Mechanica 2020, 1-7.

[27] Kalkan, E., 2003. The improvement of geotechnical properties of Oltu (Erzurum) clayey deposits for using them as barriers. PhD Thesis (in Turkish), Ataturk University, Graduate School of Natural and Applied Science, Erzurum, Turkey.

[28] Kalkan, E., 2006. Utilization of red mud as a stabilization material for preparation of clay liners. Engineering Geology 87 (3-4), 220-229.

[29] Kalkan, E., 2012. Effects of waste material-lime additive mixtures on mechanical properties of granular soils. Bulletin of Engineering Geology and the Environment 71 (1), 99-103.

[30] Kalkan, E., 2013. Preparation of scrap tires rubber fiber-silica fume mixtures for modification of clayey soils. Applied Clay Science 80-81, 117-125.

[31] Kalkan, E., 2020. A Review on the Microbial Induced Carbonate Precipitation (MICP) for Soil Stabilization. International Journal of Earth Sciences Knowledge and Applications 2 (1), 38-47.

[32] Kalkan, E., Akbulut, S., 2004. The positive effects of silica fume on the permeability, swelling pressure and compressive strength of natural clay liners. Engineering Geology 73 (1-2), 145-156.

[33] Kalkan, E., Bayraktutan, M.S., 2008. Geotechnical evaluation of Turkish clay deposits: a case study in Northern Turkey. Environmental Geology 55, 937-950.

[34] Kalkan, E. Yarbaşı, 2013. Use of marble dust waste material for stabilization of compacted clayey soils. Jökull Journal 63, 322-344.

[35] Kalkan, E., Yarbasi, N., Bilici, O., 2019. Strength performance of stabilized clayey soils with quartzite material. International Journal of Earth Sciences Knowledge and Applications 1 (1)1-5.

[36] Kalkan, E., Yarbaşı, N., Bilici, Ö., 2020. The Effects of Quartzite on the Swelling Behaviors of Compacted Clayey Soils. International Journal of Earth Sciences Knowledge and Applications 2 (2), 92-101.

[37] Karasahin, M. Terzi, S., 2007. Evaluation of marble waste dust in the mixture of asphaltic concrete. Construction and Building Materials 21, 616-620.

[38] Kayabali, K., 1997. Engineering aspects of a novel landfill liner material: bentoniteamended natural zeolite. Engineering Geology 46, 105-114.

[39] Keith, K.S., Murray, H.H., 1994. Clay liners and barriers, In: Carr, D.D. (Ed.), Industrial Minerals and Rocks, Sixth Edition. Society for Mining, Metallurgy and Exploration, Littleton, Colorado, pp. 435-452.

[40] Lv, X., Zhou, H., 2019. Shear Characteristics of Cement-Stabilized Sand Reinforced with Waste Polyester Fiber Fabric Blocks. Advances in Materials Science and Engineering 2019, 1-12.

[41] Maher, M.H., Ho, Y.C., 1994. Mechanical-properties of kaolinite fiber soil composite. Journal of Geotechnical Engineering 120 (8),1381-1393.

[42] Meunier, A., 2006. Why are clays minerals small? Clay Minerals 41, 551-566.

[43] Mitchell, J. K., 1993. Fundamentals of soil behavior. 2nd Ed., Wiley, New York.

[44] Mohamedgread, F., Yarbaşi, N., Kalkan, E., 2019. Reinforce in Engineering Properties of Clayey Soils Using Cigarette Butts and Marble Dust. European Journal of Advances in Engineering and Technology 6 (8), 31-37.

[45] Mohan, D., Jain, G.S., Sharma, D., 1973. Foundation practice in expansive soils in India. Proceedings of the 3rd International Conference on Expansive Soils, Haifa, Israel (1973), pp. 125-132.

[46] Muntohar, A.S., Widianti, A., Hartono, E., Diana, W., 2013. Engineering properties of silty soil stabilized with lime and rice husk ash and reinforced with waste plastic

fiber. Journal Materials Civil Engineering 25, 1260-1270.

[47] Murray, H.H., 2000. Traditional and new applications for kaolin, smectite, and palygorskite: a general overview. Applied Clay Science 17, 207-221.

[48] Nelson, D.J., Miller, J.D., 1992. Expansive Soils: Problems and Practice in Foundation and Pavement Engineering. John Wiley & Sons, New York.

[49] Nowamooz, H., Masrouri, F., 2008. Hydromechanical behaviour of an expansive bentonite-silt mixture in cyclic suction-controlled drying and wetting tests. Engineering Geology 101, 154-164.

[50] Ola, S.A., 1978. Geotechnical properties and behaviour of some stabilized Nigerian laterite soils. Quarterly Journal of Engineering Geology 11, 145-160.

[51] Parihar, N.S., Shukla, R.P, Gupta, A.K., 2015. Effect of reinforcement on soil. International Journal of Applied Engineering Research 10 (55), 4147-4151.

[52] Pereira, F.R., Ball, R.J., Rocha, J., Labrincha, J.A., Allen, G.C., 2008. New waste-based clinkers: belite and lime formulations. Cement and Concrete Research 38, 511-521.

[53] Pierce, C.E., Blackwell, M.C., 2003. Potential of scrap tire rubber as lightweight aggregate in flowable fill. Waste Management 23, 197-208.

[54] Popescu, M.E., 1979. Engineering problems associated with expansive clays from Romania. Engineering Geology 14, 43-53.

[55] Prabakar, J., Dendorkar, N., Morchhale, R.K., 2003. Influence of fly ash on strength behavior of typical soils. Construction and Building Materials 18 (4), 263-267.

[56] Prabakar, J., Sridhar, R.S., 2002. Effect of random inclusion of sisal fiber on strength behavior of soil. Construction and Building Materials 16, 123-131.

[57] Puppala, A.J., Musenda, C., 1998. Investigation of geofiber reinforcement method on strength, swell, and shrinkage characteristic of soils. Presented at Fifth International Conference on Composites Engineering, Las Vegas.

[58] Ranjan, G., Vasan, R.M., Charan, H.D., 1996. Probabilistic analysis of randomly distributed fiber-reinforced soil. Journals of Geotechnical Engineering Division 122 (6), 419-426.

[59] Rao, S.M., Reddy, B.V.V., Muttharam, M., 2001. The impact of cyclic wetting and drying on the swelling behavior of stabilized expansive soils. Engineering Geology 60, 223-233.

[60] Saboya, F., Xavier, G.C., Alexandre, J., 2007. The use of the powder marble by-product to enhance the properties of brick ceramic. Construction and Building Materials 21, 1950-1960.

[61] Sabtan, A.A., 2005. Geotechnical properties of expensive clay shale in Tabuk, Saudi Arabia. Journal of Asian Earth Science 25, 747-757.

[62] Sandra, T., Jeffrey, C.E., 1992. The effects of filler and admixtures on grout performance. Grouting, Soil Improvement, and Geosynthetics. Geotechnical Engineering Division of ASCE, USA 1, 337-349.

[63] Shi, B., Jiang, H., Liu, Z., Fang, H.Y., 2002. Engineering geological characteristics of expansive soils in China. Engineering Geology 67 (1), 63-71.

[64] Tang, C.S., Shi, B., Gao, W., Chen, F., Cai, Y., 2007. Strength and mechanical behavior of short polypropylene fiber rein-forced and cement stabilized clayey soil. Geotextiles and Geomembranes 25 (3),194-202.

[65] Tunç, A., 2002. Geotechnic and Its Applications on Road Engineering. Atlas Publisher, İstanbul, Turkey (in Turkish).

[66] Vidal, H., 1969. The principle of reinforced earth. Highway Research Record No: 282, 1-16.

[67] Yarbaşı, N., Kalkan, E., 2019. The Stabilization of Sandy Soils by Using the Plastic Bottle Waste. International Journal of Advance Engineering and Research Development 6 (11), 140-144.

[68] Yarbaşı, N., Kalkan, E., 2020. The Mechanical Performance of Clayey Soils Reinforced with Waste PET Fibers. International Journal of Earth Sciences Knowledge and Applications 2 (1) 19-26.

[69] Yarbaşı, N., Kalkan, E., Akbulut, S., 2007. Modification of freezing-thawing properties of granular soils with waste additives. Cold Regions Science and Technology 48, 44-54.

[70] Yetimoglu, T., Inanir, M., Inanir, O.E., 2005. A study on bearing capacity of randomly distributed fiber-reinforced sand fills overlying soft clay. Geotextiles and Geomembranes 23 (2), 174-183.

[71] Yetimoglu, T., Salbas, O., 2003. A study on shear strength of sands reinforced with randomly distributed discrete fibers. Geotextiles and Geomembranes 21, 103-110.

[72] Zaimoğlu, A.S., 2010. Freezing-thawing behavior of fine-grained soils reinforced with polypropylene fibers. Cold Regions Science and Technology 60, 63-65.

[73] Zaimoğlu, A.S., Yetimoğlu, T, 2012. Strength Behavior of Fine-Grained Soil Reinforced with Randomly Distributed Polypropylene Fibers. Geotechnical and Geological Engineering 30, 197-203.

[74] Zhang, D., Shijie, W., 2001. Mechanism of freeze–thaw action in the process of soil salinization in northeast China. Environmental Geology 41, 96-100.

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The Mechanical Properties of Granular Soils Injected by Silica Fume-Lime Mixtures

Ekrem Kalkan
Department of Civil Engineering
Engineering Faculty
Ataturk University
Erzurum, Turkey

Hamza Furkan Hartutlugil
Camborne School of Mines
Exeter University
Penryn, Cornwall
United Kingdom

Abstract: Soil In this study, granular soil material was stabilized by using injection method under laboratory conditions. As additive, the mixtures of silica fume and lime were used for this experimental study. The mixtures that are turned into slurries by adding water were injected to the granular soil media prepared in the cylindrical plastic mold. Then these samples were cured for 1, 7 and 28 days. The end of curing time, all samples were tested in accordance with unconfined compressive tests and obtained unconfined compressive strength values of injected granular soil samples were compared with that of the natural granular soil samples. As a result, it is concluded that the he mixtures of silica fume and lime can be successfully used for the improve of granular soils in the geotechnical applications.

Keywords: Granular soil, injection method, mechanical property, silica fume, lime

1. INTRODUCTION

World population growth of human is increasing day by day and the suitable soil to sustain loading from buildings or structure are becoming scarce. Due to the scarcity of land, the development of the swampy areas, mountainsides and landfill areas become the alternate places for the people to live. Hence, soil stabilization has become one of the useful solutions to treat the soil in such areas to achieve the required engineering properties and specification so that structures can be placed safely without undergoing large settlements (Kazemain and Barghchi, 2012).

The soil is one of the most important and primary media for any construction work. The strength and durability of any structure depends on the strength properties of soil (Nath et al., 2017). Soil stabilization is defined as a technique to improve the engineering characteristics in order to improve the parameters such as shear strength, compressibility, density, hydraulic conductivity. The techniques of soil stabilization can be classified into a number of categories such as vibration, surcharge load, structural reinforcement improvement by structural fill, admixtures, and grouting and other methods. There are many techniques that can be used for different purposes by enhancing some aspects of soil behavior and improve the strength and properties of soil (Edil, 2003; Kazemain and Barghchi, 2012).

The improvement of soil properties is necessary to solve many engineering problems. Soil improvement techniques can be classified in various ways, for example, mechanical, chemical, and physical stabilization (Ingles and Metcalf, 1977; Lambe and Whitman, 1979; Naeini and Mahdavi, 2009). In the mechanical stabilization, the soil density is increased by the application of mechanical forces in the case of surface layer compaction. Chemical stabilization includes incorporation of additives such as natural soils, industrial by-products or waste materials, and cementitious and other chemicals. Physical stabilization includes changing the physical conditions of a soil by means of heating or freezing (Naeini and Sadjadi, 2008; Arab, 2019; Yarbaşı and Kalkan, 2019; Yarbaşı and Kalkan, 2020; Kalkan, 2019; Kalkan et al., 2020).

Improved performance of natural and crushed aggregate is often obtained by using additives such as cement, lime, zeolite, bentonite, bitumen, cement kiln dust, flue-gas desulphurization, pulverized fuel ash, granulated blast furnace slag, sodium silicates, sodium chloride or a combination of these materials (Mayers et al. 1976; Van Ree et al. 1992; Ahmed and Lovell 1993; Dawson et al. 1995; Baldwin et al. 1997; Muroueh et al. 2001; Edil, et al. 2002; Senol et al. 2003; Petkovic et al. 2004; Hassan et al. 2005; Senol et al. 2006).

Silica fume and fly ash are extensively used in geotechnical engineering applications. These materials have low unit weight, low compressibility and high pozzolanic reactivity (Cabrera and Gray 1973; Ravina 1980; Malhotra and Carette 1982; Aitcin et al. 1984; Ozbayoglu 1993; Kalkan et al. 2007). In particular, lime stabilisation has been used successfully in such geotechnical applications as foundations, capping, embankments, piles and other earthworks. (Locat et al. 1996; Cai et al. 2006; Kalkan, 2012; Kalkan, 2018; Aydin, 2019; Kalkan, 2020); Ozer and Bayrak, 2020.

The choice of technology and methods of the soil stabilization depends on the engineering challenges that determine the formulation of injection composition. A common method of soil stabilization is cementation using hydraulic fracturing of soil layers, where the use of compositions based on cement with various mineral and chemical additives is efficient. The dry mixture of injection composition depends on the types: of the used binder, chemical additives and mineral fillers. Highly effective binders in injection compositions are: aluminate, sulfo-aluminate, ferrite-containing, expansible lightweight, weighted, low hygroscopic and belite-diatomaceous earth oil-well cements (Kroychuk, 2005; Krivoborodov et al., 2009; Bazhenov et al., 2011; Chumakov, 2011). The cost of such cements is high and not all regions of the country have them. Interest is attracted by slag, ash and sand cements, the raw materials for which are the existing waste of the fuel and metallurgical complex and natural sand (Sergeev, 1984; Krivenko and Pushkareva, 2012; Marčiulatis et al., 2015; Mackevicius et al., 2017). The results of researches show that injection compositions based on such cements have a lower cost (Zhilkina et al., 2018).

In this study the mixtures of silica fume and lime as alternative low-cost stabilizer material. The main objectives of this research are to investigate the utilizable of mixtures silica fume and lime as injection material for stabilization of granular soils in geotechnical applications. Also, to test mechanical performance of injected granular soils with mixtures silica fume and lime. The injected granular soils were subjected the unconfined compression tests and the results obtained were compared with that of natural granular soils.

2. MATERIAL AND METHODS

2.1. Materials

The granular soil material produced by grinding were selected for tests. This material obtained from limestone and crystallized limestone primary rocks were supplied from the Stone Quarry Facility of Makimsan Company in Erzurum, Turkey. The grain size distribution of the granular soil material was given in Figure 1. The soils had a density of 2.75 Mg/m^3.

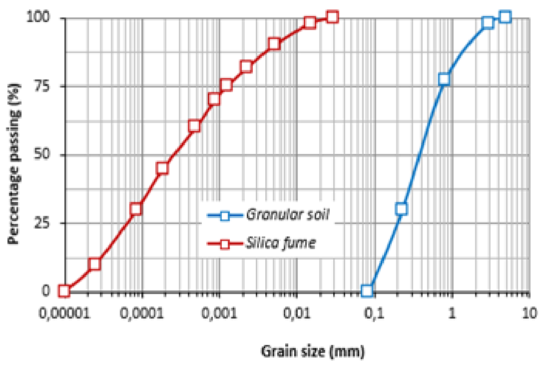

Figure 1. Grain size distribution of granular soil and silica fume

In this study, silica fume was used as waste material. The silica fume used in the tests was supplied from Ferro-Chromate Factory in Antalya, Turkey. The density of silica fume is 2.0-2.5 Mg/m^3, and the bulk density ranges from 0.3 to 0.5 Mg/m^3. The grain size distribution of silica fume was given in the Figure 1.

The lime was used as manufactured additive material in this study. The lime used in tests was supplied from Kayseri Lime Factory in Kayseri, Turkey.

2.2. Methods

2.2.1. Preparation of samples

To obtain the unconfined compressive strength values, the cylindrical divisible plastic mold with the 35 mm diameter and 70 mm height. The granular soil material was placed in to this cylindrical plastic mold at the 50% relative density. The slurry was prepared by adding water to the mixture. The mixture was including 80% silica fume and 20% lime. The slurry was taken to the hand injector and then it injected to the granular soil media in the cylindrical plastic mold by manually (Figure 2).

The maximum care has been taken to ensure that the injection is fully spread into the granular soil media. After getting full injection, the injection process was finished and the injected samples were left for their curing process. The end of curing periods, the samples were subjected to the unconfined compressive tests.

Figure 2. Injected granular soil samples

2.2.2. Unconfined compression test

The unconfined compressive strength values of natural and injected granular soil samples were determined from the unconfined compression test in accordance with ASTM D 2166. The unconfined compression test was carried out on the cylindrical samples. All of the samples had 35 mm in diameter by 70 mm in length. In this study, three cylindrical samples were prepared and tested for each combination of mixtures. The unconfined compression test was performed at a deformation rate of 0,8 mm/min. The natural and injected granular soil sample subjected to the unconfined compressive test and tested sample was given in Figure 3.

Figure 3. Injected granular soil samples; (a) under the unconfined compressive test and (b) after the unconfined compressive test

3. RESULTS AND DISCUSSION

3.1. Effects of injection on the unconfined compressive strength values of granular soil samples

The unconfined compression tests were performed to investigate the effect of injection on the unconfined compressive strength values of the granular soil samples. The unconfined compression tests were carried for the different curing periods. The results obtained from these tests were illustrated on the Figure 4. The test results showed that the injection of mixture with 80% silica fume and 20% lime improved the unconfined compressive strength values of granular soil samples. In the stabilization of the granular soil with injection of mixture with 80% silica fume and 20% lime, mixture played a significant role. The increase in the compressive strength was attributed to the internal friction of silica fume particles and the chemical reaction between silica fume and lime particles. In addition to being a highly pozzolanic material, the extremely fine silica fume particles improved the packing of the granular soil media, resulting in a denser stabilised soil (Glasser 1997; Neville and Aitcin 1998; Hassan et al. 2005; Kalkan 2006), increasing the cohesion

(Kalkan and Akbulut 2004). The increase in the compressive strength is due to the hydration and hardening that occurred between the silica fume and lime particles, enhanced by the pozzolanic properties of the waste materials (Kohno et al. 1993; Temimi et al. 1998; Sebastia et al. 2003; Kalkan 2006; Kalkan, 2012).

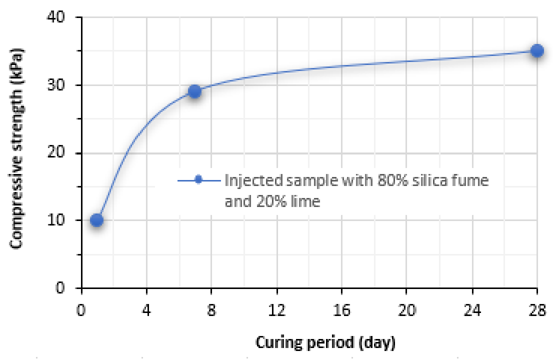

Figure 4. Effects of injection on the unconfined compressive strength values of granular soil samples

3.2. Effects of curing period on the unconfined compressive strength values of injected granular soil samples

The injected samples were cured for 1, 7 and 28 days to investigate the effects of curing times on the unconfined compressive strength values. As seen in Fig. 4, curing period increases the compressive strength values. The same results were obtained by Thompson (1968), Okagbue and Onyeobi (1999), Yarbaşı et al., 2007 and Kalkan (2012). The increase in the unconfined compressive strength with curing time is due to the action of the cementing gel materials of mixture of silica fume and lime produced following pozzolanic, hydration and chemical reactions.

4. CONCLUSIONS

In this study, the effects of mixture including silica fume and lime on the unconfined compressive strength values of injected granular soil samples. According to the test results, injection of mixtures of silica fume and lime improved the unconfined compressive strength of granular soils. Also, the curing time play a significant role on the improvement of mechanical properties of stabilized granular soil samples by injection method. As a result, the mixtures of silica fume and lime can be used as an injection material for the stabilization of the granular soils in the geotechnical applications.

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REFERENCES

[1] Ahmed, I., Lovell, C.W., 1993. Use of waste materials in highway construction: state of the practice and evaluating of the selected waste product. Transportation Research Record, 1345, TRB, National Research Council, Washington, DC, pp 1-9.

[2] Aitcin, P.C., Ballivy, G., Parizeau, R., 1984. The use of condensed silica fume in grouting. Innovative cement grouting. Publication SP-83, ACI Detroit MI, USA, pp. 1-18.

[3] Arab, M.G., 2019. Soil Stabilization Using Calcium Carbonate Precipitation via Urea Hydrolysis. Proceedings of the 4th World Congress on Civil, Structural, and Environmental Engineering (CSEE'19), April, 2019, Rome, Italy.

[4] Aydin, S., 2019. Determination of Prospective Science Teachers' knowledge levels about earthquake. International Journal of Earth Sciences Knowledge and Applications 1 (1), 28-31.

[5] Baldwin, G., Addis, R., Clark, J., Rosevear, A., 1997. Industrial byproducts in road construction-water quality effects. CIRIA Report 167. CIRIA, London.

[6] Bazhenov, Y.M., Korovyakov, V.F., Denisov, G.A., 2011. Technology of Dry Building Mixes: Study Guide, ACU, Moscow.

[7] Cabrera, J.K., Gray, M.M., 1973. Specific surface, pozzolanic activity and composition of pulverized fuel ash. Fuel Journal 52, 213-215.

[8] Cai, Y., Shi, B., Ng, C.W.W., Tang, C., 2006. Effects of polypropylene fiber and lime admixture on engineering properties of clayey soil. Engineering Geology 87, 230-240.

[9] Edil, T.B., 2003. Recent advances in geotechnical characterization and construction over peat and organic soils" Proceedings 2nd International Conference on Advances in Soft Soil Engineering and Technology. (Eds). Huat et al. Malaysia: Putrajaya, pp. 3-25.

[10] Dawson, A.R., Elliot R.C., Rowe G.M., Williams, J., 1995. An assessment of the suitability of some industrial by-products for use in pavement bases in the United Kingdom. Transport Research Record, No: 1486, pp 114-123.

[11] Edil, T.B., Benson, C.H., Bin-Shafique, M., Kim, W., Tanyu, B.F., Senol, A., 2002. Field evaluation of construction alternatives for roadway over soft subgrade. Journal of Transport Research Record 178, 36-48.

[12] Glasser, F.P, 1997. Fundamental aspects of cement solidification and stabilization. Journal of Hazardous Materials 52, 151-170.

[13] Hassan, H.F., Taha, R., Al Rawas, A., Al-Shandoudi, B., Al-Gheithi, K., Al-

[14] Barani, A.M., 2005. Potential uses of petroleum-contaminated soil in highway construction. Constructing and Building Materials 19, 646-652.

[15] Ingles, O.G, Metcalf, J.B., 1977. Soil Stabilization Principles and Practice. 2nd ed, Australia Butterworths.

[16] Kalkan, E., 2006. Utilization of red mud as a stabilization material for preparation of clay liners. Engineering Geology 87 (3-4), 220-229.

[17] Kalkan, E., 2012. Effects of waste material–lime additive mixtures on mechanical properties of granular soils. Bulletin of Engineering Geology and the Environment 71, 99-103.

[18] Kalkan, E., 2020. A Review on the Microbial Induced Carbonate Precipitation (MICP) for Soil Stabilization. International Journal of Earth Sciences Knowledge and Applications 2 (1), 38-47.

[19] Kalkan, E., Akbulut, S., 2004. The positive effects of silica fume on the permeability, swelling pressure and compressive strength of natural clay liners. Engineering Geology 73, 145–156.

[20] Kalkan, E., Yarbaşı N, Akbulut, S., 2007. Use of solid waste-lime mixtures for soil improving. Symposium of Erdogan Yuzer Engineering Geology, 6-7 September 2007, ITU Mining Faculty, Istanbul, Turkey, pp 253-262.

[21] Kalkan, E., Yarbasi, N., Bilici, O., 2019. Strength performance of stabilized clayey soils with quartzite material. International Journal of Earth Sciences Knowledge and Applications 1 (1)1-5.

[22] Kalkan, E., Yarbaşı, N., Bilici, Ö., 2020. The Effects of Quartzite on the Swelling Behaviors of Compacted Clayey Soils. International Journal of Earth Sciences Knowledge and Applications 2 (2), 92-101.

[23] Kazemain, S., Barghchi, M., 2012. Review of soft soils stabilization by grouting and injection methods with different chemical binders. Scientific Research and Essays 7 (24), 2104-2111.

[24] Kohno, K., Amo K., Ogawa Y., Ikezoe, Y., 1993. Effect of admixture consisting of finely ground silica and red mud on properties of high strength concrete for products. In: Proceedings of the 4th EASEC, Seoul, Korea, I, 1437.

[25] Krivoborodov, Y.R., Burlov, A.Y., Burlov, I.Y., 2009. The use of recoverable resources for cement production. Stroitel'nye Materialy, 2.

[26] Krivenko, P.V., Pushkareva, E.K., 2012. Cement and concretes based on ashes and slags, IPK Express-Polygraph, Kiev.

[27] Kroychuk, L.A., 2005. Russian cement industry. Stroitel'nye Materialy 1.

[28] Kuznetsova, T.V., 2010. Production and application sulfoaluminate Cements. Stroitel`nye Materialy 3.

[29] Lambe, T.W., Whitman, R.V., 1979. Soil Mechanics. SI version, New York, Wiley.

[30] Locat, J., Tremblay, H., Leroueil, S., 1996. Mechanical and hydraulic behavior of a soft inorganic clay treated with lime. Canadian Geotechnical Journal 33, 654-669.

[31] Mackevicius, R., Slizyte, D., Zhilkina, T., 2017. Procedia Engineering 172, 681-684.

[32] Marčiulatis, V., Sližyte, D., Mackevičius, R., Zhilkina, T.A., 2015. Engineering Structures and Technologies 7(3), 140-145.

[33] Malhotra, V.M., Carette, G., 1982. Silica Fume Concrete, Properties, Applications, and Limitations. 10th Annual Meeting of the Institute of Concrete Technology, Slough, England, pp 1-23.

[34] Mayers, J.F., Pichumani, R., Kapples, B.S., 1976. Fly ash as a construction material for highways. U. S. Department of Tranportation Report No: FHWA-IP-76-16, Washington DC, USA.

[35] Muroueh, U., Eskola, P., Laine-Ylijoki, J., 2001. Life-cycle impacts of the use of industrial by-products in road and construction. Waste Manage 21:271-277.

[36] Nath, B.D., Molla, M.K.A., Sarkar, G., 2017. Study on Strength Behavior of Organic Soil Stabilized with Fly Ash. International Scholarly Research Notices 2017, 5786541.

[37] Naeini, S.A., Mahdavi, A., 2009. Effect of polymer on shear strength of silty sand. EJGE 14, 1-11.

[38] Naeini, S.A., Sadjadi, S.M., 2008. Effect of Waste Polymer Materials on Shear Strength of Unsaturated Clays. EJGE 13, 1-12.

[39] Neville, A.M., Aitcin, P.C., 1998. High-performance concrete-an overview. Material Structure 31, 111-117.

[40] Okagbue, C.O., Onyeobi, T.U.S., 1999. Potential marble dust to stabilize red tropical soils for road construction. Engineering Geology 53, 371-380.

[41] Ozbayoglu, F.U., 1993. Usage of fly ashes with additive bentonite, lime and cement in stabilization of sandy soils. In: Symposium on the Usage of Industrial Wastes in Construction Areas, Ankara, 103-117.

[42] Ozer, C., Bayrak, E., 2020. Coulomb Stress Changes after 11 May 2017 Askale-Erzurum (NE Turkey) Earthquake (Mw = 4.7). International Journal of Earth Sciences Knowledge and Applications 2 (1), 13-18.

[43] Ravina, D., 1980. Optimized determination of PFA fineness with reference to pozzolanic activity. Cement and Concrete Research 10, 573-580.

[44] Sebastia, M., Olmo, I.F., Irabien, A., 2003. Neural network prediction of unconfined compressive strength of coal ash-cement mixtures. Cement and Concrete Research 33, 1137-1146.

[45] Senol, A., Bin-Shafique, M., Edil, T.B., Benson, C.H., 2003. Use of Class C fly ash for the stabilization of soft soil as subbase. ARI Bulletin of Istanbul Technical University 53, 89-95.

[46] Senol, A., Edil, T.B., Bin-Shafique, M., 2006. Soft subgrades' stabilization by using various fly ashes. Resour Conserv Recycling 46, 365-376.

[47] Sergeev, A.M., 1984. Use of Energy Industry Wastes in Construction Industry, Budivelnyk, Kiev.

[48] Temimi, M., Ben Amor, K., Camps, J.P., 1998. Making building products by extraction and cement stabilization: limits of the process with montmorillonite clay. Applied Clay Sciences 13, 245-253.

[49] Thompson, M.R., 1968. Lime treated soils for pavement construction. ASCE J. Highway Division 94 HW-2 59-67.

[50] van Ree, C.C.D.F., Weststrate, F.A., Meskers, C.G., Bremmer, N.C., 1992. Design aspects and permeability testing of natural clay and sandbentonite liners. Geotechnique 42, 49-56.

[51] Yarbaşı, N., Kalkan E., 2019. The Stabilization of Sandy Soils by Using the Plastic Bottle Waste. International Journal of Advance Engineering and Research Development 6 (11), 140-144.

[52] Yarbaşı, N., Kalkan E., 2020. The Mechanical Performance of Clayey Soils Reinforced with Waste PET Fibers. International Journal of Earth Sciences Knowledge and Applications 2 (1) 19-26.

[53] Yarbaşı, N., Kalkan, E., Akbulut, S., 2007. Modification of the geotechnical properties, as influenced by freeze–thaw, of granular soils with waste additives. Cold Regions Science and Technology 48 (1), 44-54.

[54] Zhilkina, T., Sychugov, S., Gumeniuk, A., Mackevicius, R., Turchin, V., Vasilev, V., Zakirov, M., Ilinsky, A., 2018. Technology of soil stabilization with cementsand grouting mortar with optimal aggregate grading. MATEC Web of Conferences 193, 05046 (ESCI 2018).

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Investigation of Dependent Variables on Utilizing Cotton Simulation Model

Abolfazl Biglar Beigi
Hamedan, Iran

Abstract: This research is focused on utilizing cotton simulation model (GOSSYM) to investigate the impact of different dependent variables such as different amount of Carbone Dioxide, rainfall, different Nitrogen Level, UV-B with or without irrigation, or different soil type in a MID-season cultivar for predicting and finding the influence of environmental factors on cotton yield, plant height, main stem nodes, and major phenological events such as squaring, flowering and boll opening during 30 years from 1964 to 1993 in Razan, Hamedan, Iran.

Keywords: Carbone Dioxide; phenological events; RegCM climate model ; Nitrogen level; MID-season

1. INTRODUCTION

Different variety of factors either climatic or inputs affect cotton productivity. There are various factors that influence cotton yield [1-2]. The actual daily solar radiation, maximum and minimum air temperatures, rainfall, and wind speed for 30 years (1964 to 1993) were used as current or ambient weather input scenarios for the model[3-6]. Changes in climate were calculated from results of a regional climate model (RegCM) nested within a General Circulation Model (GCM) from National Center for Atmospheric Research (NCAR) at Boulder, Colorado. The quantified changes in the future climate (i.e., maximum/minimum temperatures, solar radiation, precipitation, wind speed) were predicted using the RegCM climate model [7].

The weather input required to run GOSSYM is on a daily basis. Therefore, the projected monthly means for future weather parameters were used to create daily future weather files by modifying the daily current weather based on the assumption that changes in daily weather parameters will be constant for each month.[8-11] The monthly mean maximum and minimum temperature changes were added to and the ratios for the other three parameters (precipitation, solar radiation, and wind speed) were multiplied with the corresponding values of the daily 30-year current weather parameters to generate the daily future weather files for 30 years (future climate scenario). This methodology[12], however, retains the existing natural variability in the historic weather for the 30 years.

2. METHODOLOGY

In this research by applying the cotton simulation model, GOSSYM, all measurements was carried out. Data was recorded for 30 years and the model was written in Fortran to run the model and get the results. There were different scenarios, from MID- season cotton cultivar in rainfed or irrigated conditions, two different soil types (clay and loamy soil) and different planting dates and different Nitrogen level [12-14]. After running the model, data were collected in an excel file to do some statistics and plotting some graphs in order to investigate in more details. The results in the format of table and results is provided below.

3. RESULTS AND DISCUSSION

As it can be seen in Fig.1, Fig.2 and Fig.3 the slop for both graph is so small so, increasing co2 don't affect corn height and maximum leaf area index and number of nodes in both irrigated or rainfed areas significantly, even fertilizer or water was supplied. There is a slightly decreasing, increasing for corn height and Maximum Leaf Area Index respectively but there is not a constant trend for number of nodes.

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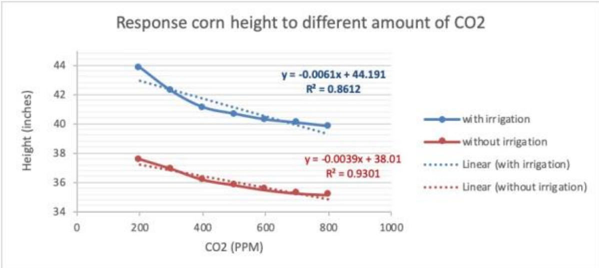

Figure 1. Response corn height to different amount of CO2 with and without irrigation over 30 years simulation period

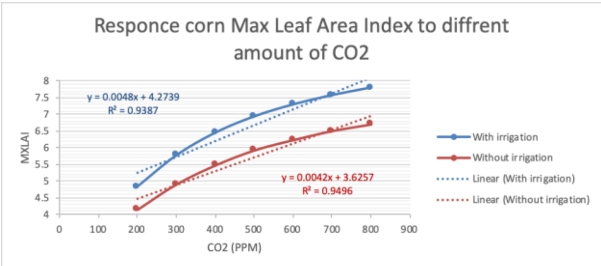

Figure 2. Response Corn Maximum Leaf Area Index to different amount of CO2 with and without irrigation over 30 years simulation period.

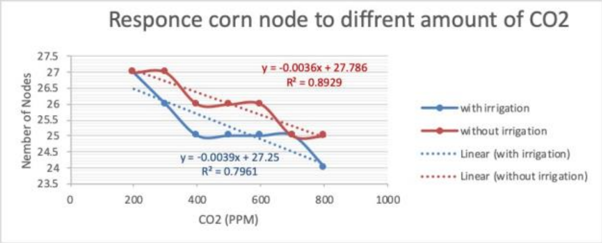

Figure 3. Response corn nodes to different amount of CO2 with and without irrigation over 30 years simulation period.

As it can be seen in Fig.1, Fig.2 and Fig.3 the slop for both graph is so small so, increasing co2 don't affect corn height and maximum leaf area index and number of nodes in both irrigated or rainfed areas significantly, even fertilizer or water was supplied. There is a slightly decreasing, increasing for corn height and Maximum Leaf Area Index respectively but there is not a constant trend for number of nodes

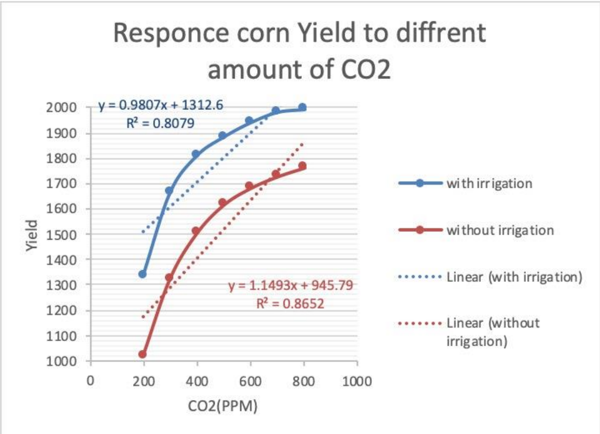

Figure 4. Response corn yield to different amount of CO2 with and without irrigation over 30 years simulation period.

As it can be seen in Fig.4, corn yield will be increased by increasing the amount of co2 and the yield in irrigated situation is more than rainfed and the importance of irrigation in increasing the yield was shown clearly.

Table 1. the impact of rainfall on different corn parameters under constant CO2 simulated over 30 years (1964 to 1993).

Rainfall Factor	Height	MXLAI	Node	Yield	DAE FSQ
0.25	22.17	4.83	27	1336	27
0.5	27.64	5.77	26	1665	27
0.75	32.9	6.45	25	1812	27
1	36.17	6.94	25	1886	27
1.25	38.58	7.3	25	1943	27

Table 2. the impact of different amount of CO2 on different corn parameters over 30 years (1964 to 1993

CO2 PPM	Rainfall Factor	Height	MXLAI	Node	Yield
200	1	43.8	4.83	27	1336
300	1	42.21	5.77	26	1665
400	1	41.1	6.45	25	1812
500	1	40.65	6.94	25	1886
600	1	40.26	7.3	25	1943
700	1	40.04	7.58	25	1984
800	1	39.8	7.81	24	1995
200	1	37.52	4.15	27	1020
300	1	36.88	4.91	27	1325
400	1	36.17	5.48	26	1505
500	1	35.81	5.93	26	1617
600	1	35.48	6.24	26	1683
700	1	35.26	6.51	25	1729

Different amounts of co2 do not have any effects on days to first square, first flower blossom and first open boll. They remained at 27, 49 and 89 respectively. It means 27 days after emergence to appear first square, 49 days after emergence for first blossom and 89 days after emergence to first open boll is needed.

4. INFLUENCE OF RAINFALL ON CROP GROWTH AND YIELD:

Rainfall in one of the important factor for researchers and farmer. It is not necessary to arrange irrigation by having the good amount precipitation on time.

As it can be seen in table.2, increasing rainfall does not have any effect on corn phenology processes which are be constant in 27, 49 and 89 days after emergence respectively for first square, first flower blossom and first open boll. there is not a constant trend for number of nodes also (Fig. 7).

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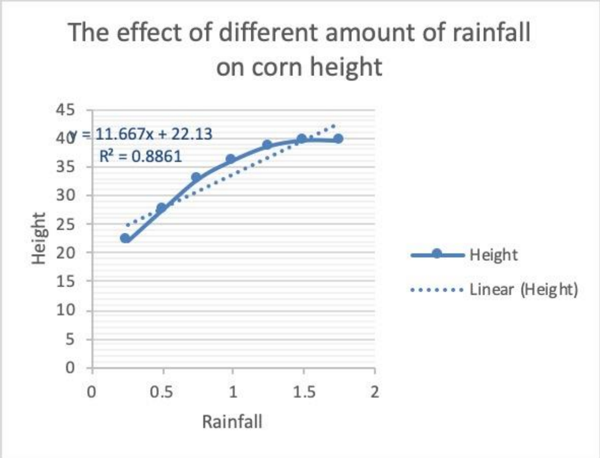


Figure 5. The effect of different amount of rainfall on corn height for 30 years..

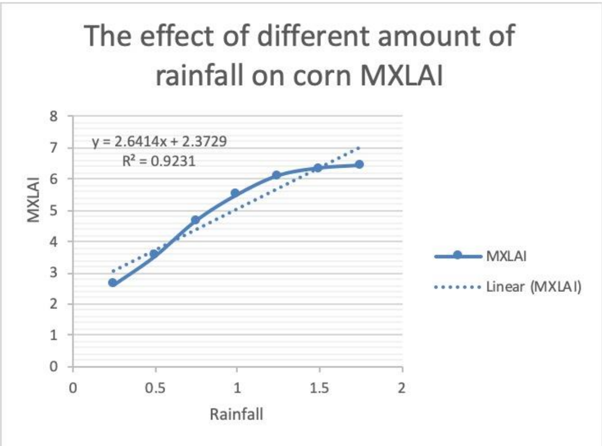


Figure 6. The effect of different amount of rainfall on corn MXLAI for 30 years.

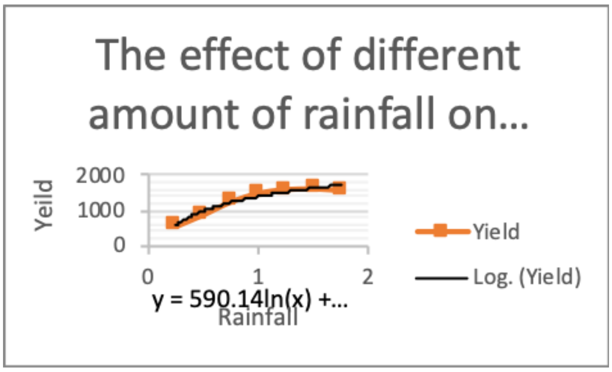


Figure 7. The effect of different amount of rainfall on yield for 30 years.

As it is shown in Fig. 5, Fig.6 and 7, by increasing rainfall, there is a increasing trend in corn height and max leaf area index. The increasing rainfall from 0.25 to 0.5 and 0.5 to 0.75 have more effect on yield rather than 1 to 1.25 and 1.25 to 0.5.

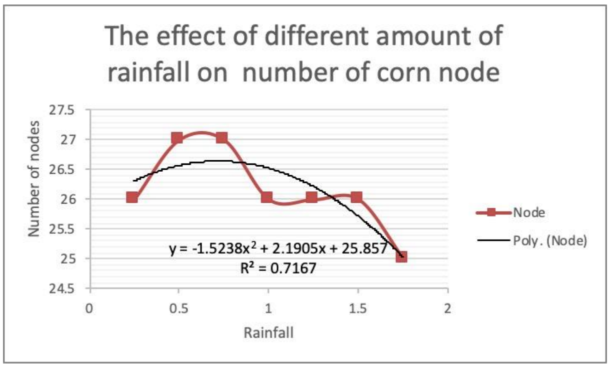


Figure 8. The effect of different amount of rainfall on number of corn node.

5. INFLUENCE OF NITROGEN ON CROP GROWTH AND YIELD UNDER TWO DIFFERENT SOIL TYPES

Nitrogen is a critical factor for plants. And different soil types have different ability to keep fertilizers in themselves. Moreover, irrigation or rainfall have an important impact on keeping Nitrogen fertilizer in soil.

Table 3. Influence of nitrogen on crop growth and yield under two different soil types over a simulation period of 30 years

CO2 (ppm)	Soil type	Nitrogen Level	Height	MXLAI
400	1	1	35.27	5.78
400	1	2	37.62	6.18
400	1	3	39.48	6.37
400	1	4	41.1	6.45
400	1	1	32.12	5.12
400	1	2	33.61	5.39
400	1	3	34.95	5.47
400	1	4	36.17	5.48
400	2	1	34.73	5.56
400	2	2	37.44	6.01

400	2	3	39.51	6.2

This simulation investigates the influence of nitrogen in 4 different amount of nitrogen fertilizer (50, 100,150 and 200lbs) under 2 different soil types (1 for clay and 2 for loam) with and without irrigation.

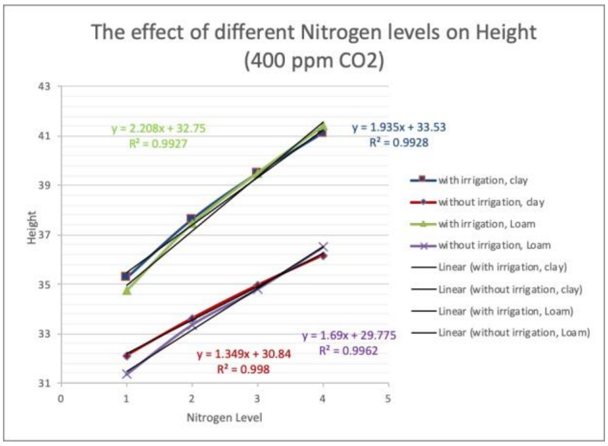


Figure 9 .The effect of different Nitrogen levels on Height (400 ppm CO2) over 30 years

As it can be seen in Fig. 9, increasing Nitrogen fertilizer cause to increase corn height but the impact in irrigated condition is more than rainfed condition. The irrigation condition has more effect than type of soil (clay or loam)

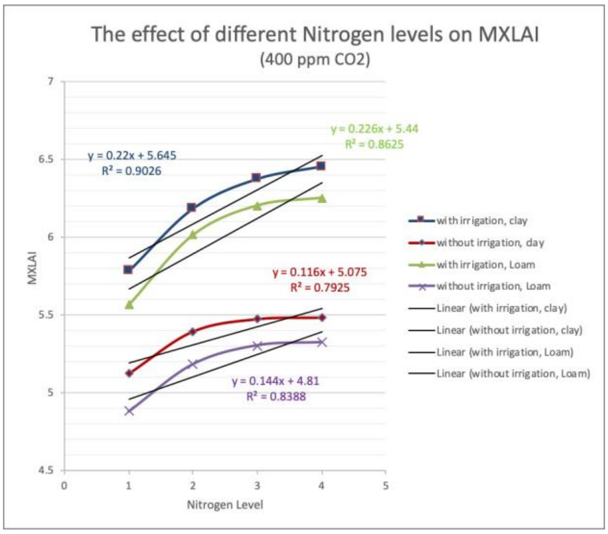


Figure 10 . - The effect of different Nitrogen levels on MXLAI (400 ppm CO2) over 30 years

As it can be seen in Fig. 10, increasing Nitrogen fertilizer cause to increase corn max leaf area index but the impact in irrigated condition is more than rainfed condition. The irrigation condition has more effect than type of soil (clay or loam) but the max leaf area index in clay soil is more than loamy soil. On both soil types maximum LAI remained at stable growth under irrigated conditions but reduced slightly under non- irrigated conditions for all amount of fertilizer (N) applied.

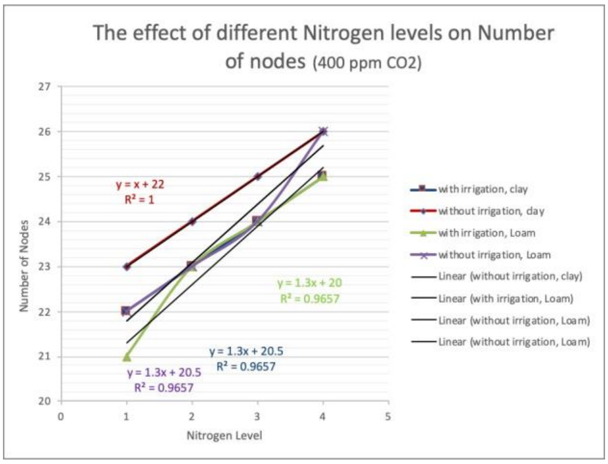
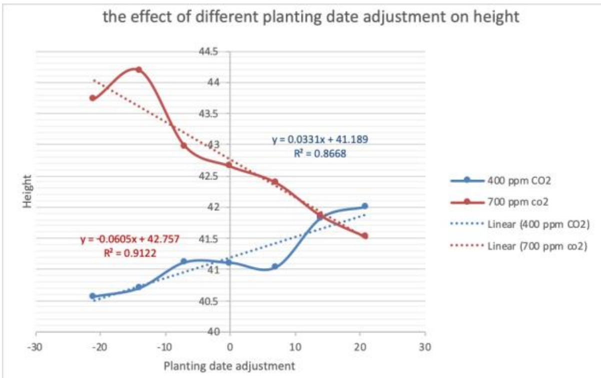


Figure 11 . - The effect of different Nitrogen levels on MXLAI (400 ppm CO2) over 30 years

The number of nodes does not have any difference in clay soil with or without irrigation conditions. But by increasing the amount of nitrogen, the number of nodes increased in clay soil too. The difference is just when the type of soil change to loam.

6. FUTURE WEATHER SCENARIOS WITH MITIGATION OPTIONS

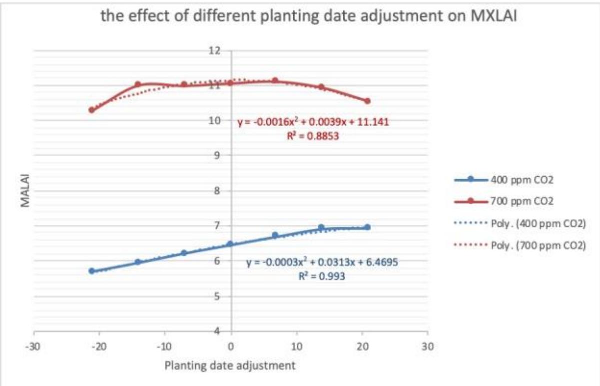
Plant growth and production can be affected by weather patterns together with other external factors. It can effect on plant phonological processes as well. Under current carbon dioxide conditions, cotton cultivar tends to be in high production, but it will be greatly affected by the future climate condition. In order to increase cotton production in a changing climate condition, one option probably is changing the planting dates.



Base on the simulations, changing planting dates, -21, -14 and -7 days earlier than standard planting date, shows that plant growth remains constant under present CO2 level (400 PPM). But under future CO2 concentration, 700PPM, cotton plants are taller when planted at earlier planting dates but remains constant in height after planting at zero days and later. In addition, based on simulations, cotton cultivar had more LAI at future climate condition than plants grown at the current conditions. In future condition, in comparison to current condition, plants had more nodes when planted at earlier days.

Based on model predictions for cotton yield, over a 30 year on 700 ppm CO2 level, and adjusted planting date, yield will decrease as compare to the current condition, (700ppm CO2 concentration). Maximum decreased occurred at -21 earlier planting days at 37% and the least decreased at 21 days later plant date at 25%. Changing scenarios and planting dates also have huge effects on cotton plant phenology, where first squaring, first flower bloom and first open boll will take place much earlier under future 700ppm CO2 concentration.

By increasing the planting date from -21 to 0, days to first square, first flower blossom and first open boll will appear earlier. But it does not have any effect on 0 to +21 for to first square and first open boll.



7. CONCLUSION

Cotton simulation model (GOSSYM), is a very important tool for researchers and farmers, especially during cotton growth which it can be easily affected by various factors. It is important to have proper management practices such as irrigation and fertilization program for cotton in order to gain maximum yields. By having some models like GOSSYM, farmers can notify that by every condition what they can do to avoid reduction in yield and growth or sometimes they know which factors effect on phenological processes.

8. Acknowledgment

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9. REFERENCES

[1] Ourang, Armin, SoheilPilehvar, MehrzadMortezaei, and Roya Damircheli. 2017 "Effect of aluminum doped iron oxide nanoparticles on magnetic properties of the polyacrylonitrile nanofibers." *Journal of Polymer Engineering* 37, no. 2 : 135-141..

[2] JALALI, ZOHREH, ASL VAHID HADDADI, Iman Shabani, Masoudsoleimani, Abbas Shafiee, And Roya Damircheli. 2014 "Improving Biocompatibility Of The Polyacrylonitlienanofibrous Scaffolds." .

[3] JALALI, ZOHREH, ASL VAHID HADDADI, Iman Shabani, Masoudsoleimani, And Roya Damircheli. 2014"A Novel Method For Producing Gelatin Nanofibers Contains Hydroxyapatite Nanoparticles." .

[4] Damircheli, Roya, Hamid Mirzadeh, Herish Moradi, Yasser Ghazizadeh, And Zohreh Jalali. 2014 "Electrospun Nanofibrous Scaffolds Based On Alginate For Skin Tissue Engineering."

[5] Damircheli, Roya, Hamid Mirzadeh, Herish Moradi, Yasser Ghazizadeh, And Zohreh Jalali. 2014"Electrospun Nanofibrous Scaffolds Based On Chitosan For Skin Tissue Engineering." .

[6] Pathak, Rohit, Razieh Barzin, And Ganesh C. Bora. 2018 "Data-Driven Precision Agricultural Applications Using Field Sensors And Unmanned Aerial Vehicle." *International Journal Of Precision Agricultural Aviation* 1, No. 1.

[7] Barzin, Razieh, Amin Shirvani, and Hossein Lotfi. 2017 "Estimation of daily average downward shortwave radiation from MODIS data using principal components regression method: Fars province case study." *International agrophysics* 31, no. 1 : 23-34.

[8] A Sescu, L Taoudi, M Afsar , Iterative control of Görtler vortices via local wall deformations, *Theoretical and Computational Fluid Dynamics 32 (1), 63-72*

[9] A Sescu, L Taoudi, MZ Afsar, DS Thompson Control of Gortler vortices by means of staggered surface streaks, *46th AIAA Fluid Dynamics Conference*, 3950

[10] Bastani, A. F., & Damircheli, D. (2017). An adaptive algorithm for solving stochastic multi-point boundary value problems. *Numerical Algorithms*, *74*(4), 1119-1143.