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The Acquisition of Tampers Quantity Instead of Compaction Energy in Time Scheduling of Dynamic Compaction

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ABSTRACT

A soil exploitation project was introduced and a summary of the obstacles faced in the project was stated. Based on the investigation a compensatory action plan was proposed. The main factors that were considered in developing a compensatory action plan during the revision of the time schedule was discussed. Based on the extensive investigations, tamping quantity was considered as the main determinative factor. The influencing factors was 1) the alteration of the exploitation soil comprising a 50-50 percent of former borrow area and the new borrow area which had the required engineered specifications 2) the proposal of a new pattern for DC. In the compensatory action plan this matter was considered based on the selected pattern by application of total drop quantity to gain a realistic prediction for the schedule plan. 3) As a result of the existence of fine-grained soil in the mix, the time needed for dissipation of excess pore water pressure due to the heavy tamping or heavy seasonal rain between 3 phases and even in each phase alone was considered as a function of tamper quantity. 4) The mobilization of cranes between tamping points linked with tampers quantity based on the DC phases 5) The deficiency of cranes was calculated based on the new compensatory action plan. Since all of these factors' functionality can be linked to tamping quantity, it was found that this trend is a good way for consideration of parameters that can delay the project and also as a measure for compensatory action plan.

Keywords:

Dynamic compaction, Time schedule, Tamper, Soil treatment, Clay.

1. Introduction

Dynamic compaction (DC) is a simple, cost effective and popular soil treatment system among geotechnical engineers that can effectively improve soil specification even in significant depth[1]. The procedure consists of tamping the ground using heavy pounders by means of special cranes. Number of impacts and the weight of pounders are obtained by means of pilot studies on site and also existing empirical solutions to reach the acceptance site criteria[2]. Dynamic replacement (DR) somehow has the same mechanism with DC except the pounders are used for driving granular soil into the weak soil stratum[3]. The land under reclamation might be a wide range of an exploitation of sea or lake or construction demolition dump area and so on. Soils ranging from fine-grained to alluvium layers and coarse materials can be treated using DC or DR methods. One of the challenges in ground improvement projects is the determination of the project duration as there are many factors that can influence the field operation which even in the case of extensive preliminary site investigation remains unknown to designers. The anisotropy of bed soil in the reclamation area[4], alteration of exploitation soil and borrow areas, long dissipation time for excess pore water pressure as a result of heavy tamping [5, 6], the weight and the Height of the tampers release based on the approved pattern [4], the existence of oversize aggregates beyond specified range of project specifications, the existence of high fine-grained in borrow mine, seasonal floods and heavy rains [7] and cranes repeating break downs as a result of very cold or very hot weather are the common issues that is encountered in most of DC or DR projects. Beside all of these mentioned factors, the problem of failure in meeting field tests acceptance criteria such as standard penetration test (SPT), cone penetration test (CPT) and pressure-meter test is another main issue that causes high delay in DC and DR reclamation projects. In preparation of project time schedule, the common practice is the acquisition of the tamper's energy as the effective parameter in calculating the weight factor and the resultant S-curve diagram. The tampers energy (Ton. Meter) is the resultant of multiplication of the tamper's weight (Ton) and the drop height (Meter). The tampers energy is usually divided in three parts: phase 1 that is heavy tamper's weights, phase 2 that is medium tamper's weights and phase 3 that is the ironing. Considering the tamping energy alone and neglecting the above-mentioned factors result in an unrealistic time schedule. This article deals with the acquisition of tamper quantity instead of compaction energy in time scheduling of DC and DR ground improvement operations by describing the complex geotechnical issues that might significantly affect the project schedule timeline based on a case history.

2. Description of the site

The project that would be discussed here consists of exploitation of 29.37-acre land reclamation and nearly 1,300,000 m3 earthwork that would be treated by DC and DR method.

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Figure 1. The location of the exploitation area from google maps view.

3. Project time schedule and compensatory action plan

In the project the preliminary work breakdown structure (WBS) for treatment operation was done based on the tamper's energy. The total project time was 24 months. As the time of the project had passed, as a result of different factors that would be discussed, a high amount of delay was observed in the project. The delay was deteriorated even as the contractor had added night-shifts. Since the client could not observe any significant change in the overall progress of the project, the consultant and client technical team investigated the factors responsible for such a great delay in the treatment operation. Based on the control project report there was a 14.78 percent delay in the project in the 29th week (203th of 672 days of project time).

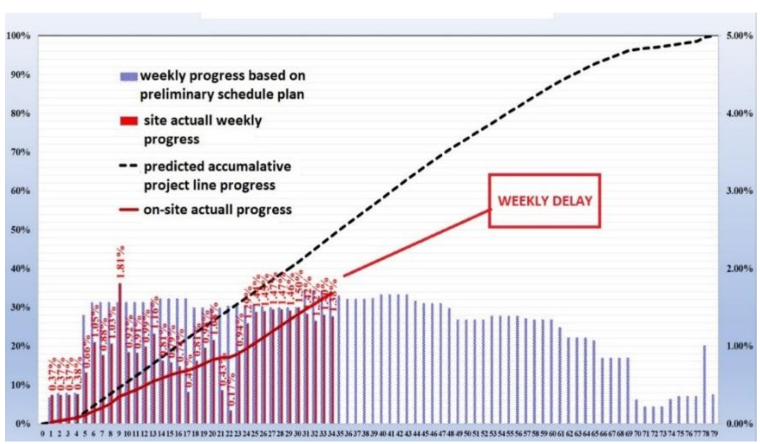

Figure 2. The S-curve of the project in the 29th week.

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4. New DC pattern

In order to compensate for the delay in the project the following solutions have been proposed by the technical team. Since 33% of the project DC pattern was still not determined because of poor borrow material, a trial plan with three cases of compaction detail and also sand column was proposed and the time needed for those tests was included in the project time schedule. Since the DC plans and sand columns should have been done simultaneously, the final and reserved plans results would be determined to prevent more delay in the project. The first three patterns are shown in Figure 3 and Table 1. The proposed pattern is shown in Table 2. As it can be seen in the second and third patterns the dimension of the treatment area has decreased considerably. Since the poured exploited soil had a very high amount of fine-grained portion, a much higher energy should be applied to compensate for the energy transmission loss and induce the required compaction underneath. The former patterns had much lesser tamper weight and drop Height as 20 ton and 10-meter drop height. It is clear that since in the second proposed pattern the height and weight has increased, the operation time would increase considerably. In the compensatory action plan this matter was applied to gain a realistic prediction for the schedule plan. In the case of the application of energy instead of the number of tampers dropped, the resultant plan would not reflect the real operation in the field.

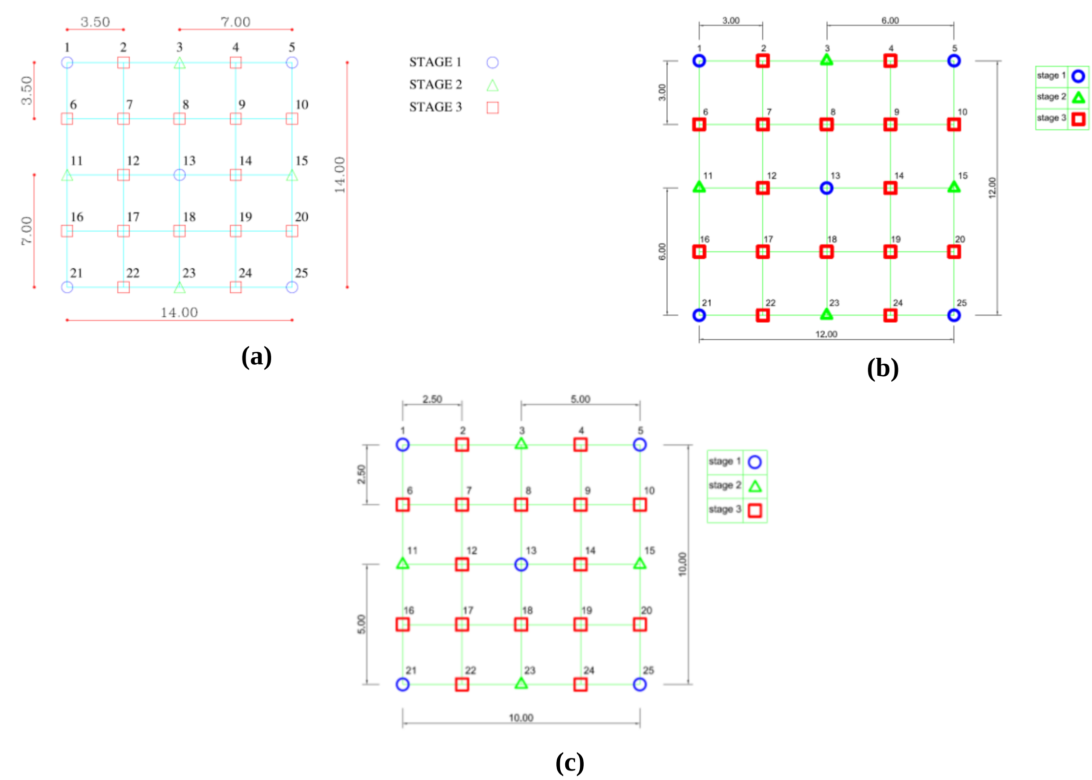


Figure 3. The proposed dynamic compaction pattern for pilot test (a) pattern 1 (b) pattern 2 (c) pattern 3.

Table 1. The detailed operation procedure of proposed dynamic compaction pilot test for pattern 1.

Number of drops	Height of release	Tamper weight	Point number
12	20	30	1,5,13,21,25
12	20	30	3,11,15,23
12	10	15	Other points

Table 2. The detailed operation procedure of proposed dynamic compaction pilot test for pattern 2.

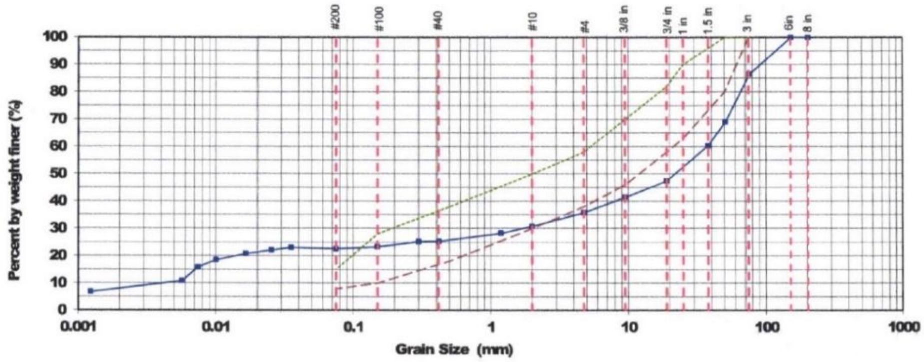
Number of drops	Height of release	Tamper weight	Point number
12	25	30	1,5,13,21,25
12	25	30	3,11,15,23
10	10	20	Other points

Table 3. The detailed operation procedure of proposed dynamic compaction pilot test for pattern 3.

Number of drops	Height of release	Tamper weight	Point number
12	25	28	1,5,13,21,25
12	25	28	3,11,15,23
10	10	20	Other points

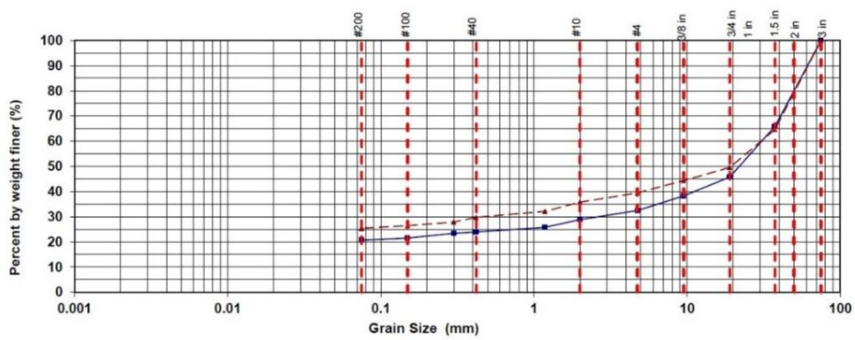
5. Soil mix and sieve analysis

The existence of a high percentage of fine-grained is not desirable although case studies reported in treatment of fine-grained soil with special considerations [8-10]. As the result of high content of fine-grained in the borrow area, a new borrow area was examined and necessary tests as sieve analysis and Atterberg tests were performed immediately to examine the adequacy of soil. The new and the former borrow are sieve analysis is shown in figure 3 respectively. Since the second borrow area has a coarse structure, a 50-50 mix was proposed to alleviate the problem of soil's grading issue. The sieve analysis test result of the mix soil sample is shown in figure 4. By modification of the exploitation soil, there would be more reliability regarding the field tests like SPT or CPT and the necessity for repeating the DC or DR in untreated areas that would probably fail the required technical specification would be lessened. Since the re-compaction of an area would impose a great delay in the compensatory action plan, quality control of the borrowed material had a greater importance compared to the beginning of the project so the number of soil tests was revised. Based on the new mix design and the new DC and DR patterns, the quantity of tamper drops was determined accurately instead of energy and it was considered in the compensatory action plan. One of the most important matters in the compensatory action plan was the determination of the exact required cranes capacity and also the exact position of the cranes in the time schedule operational field plan.



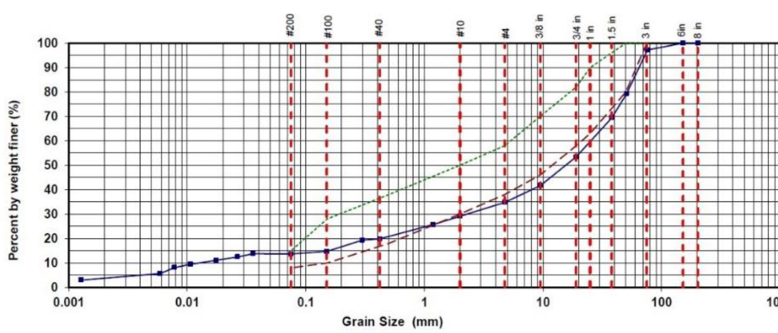
Material	symbol	PERCENT OF BREAKAGE	$D_{10\ (mm)}$	$D_{30\ (mm)}$	$D_{60\ (mm)}$	Passing#200	Sand	LL	PL	PI	UNIFIED
SH13.2	—■—	-	0.005	1.746	37.583	22.5%	13%	31.2	17.8	13.4	GC

(a)



BH/TP No.	symbol	DEPTH (m)	$D_{10\ (mm)}$	$D_{30\ (mm)}$	$D_{60\ (mm)}$	Passing#200	Sand	LL	PL	PI	UNIFIED
S.1	—■—	1.0	0.0362	2.8747	32.0904	20.7%	12%	-	-	-	GM
S.2	--▲--	2.0	0.0295	0.5032	31.8173	25.4%	14%	-	-	-	GM

(b)



Material	symbol	PERCENT OF BREAKAGE	$D_{10\ (mm)}$	$D_{30\ (mm)}$	$D_{60\ (mm)}$	Passing#200	Sand	LL	PL	PI	UNIFIED
SZ1.1 , SZ1.2	—■—	-	0.010	2.434	26.871	13.6%	21%	NP	NP	NP	GM

(c)

Figure 4. The sieve analysis of the soil for exploitation (a) first borrow area (b) new borrow area (c) 50-50 percent mix soil.

It can be seen that even in the soil Mix the percentage of fine-grained is still high (13.6% under #200 sieve). The technical specification of the contract limits the fine-grained to maximum 5%. Because of scarcity of borrowed material, the provision of the qualified soil was one of the great challenges of the project. The high amount of fine-grained would dissipate the tamping energy and cause a considerable reduction in overall DC operation. Another issue regarding the existence of high amounts of fine-grained soil is that when the degree of saturation increases then the dissipation of tamping energy would be increased too which the case was when the operation passed the coastal line. The dissipated energy is transformed mostly as excess pore pressure in the soil column. In the case of high excess pore water pressure there must be a 3 to 10 days delay between the tamping periods in order to give the necessary time for dissipation of the generated excess pore pressure. In the case of a high amount of occurrence of heave in the surrounding soil column the operation should be stopped immediately to let the excess pore pressure dissipate. Since the dumped soil for DC compaction had a 10 to 14 percent fine-grained portion with high saturation amount, it was necessary to consider and predict exactly the crane's locomotion on site. The energy trend that is common in preparation of project time-schedule don't account for such complex procedures described above. Considering the tamping quantity is the only way for consideration of this matter that was included in the compensatory action plan in detail.

6. Flood and heavy rains

Another issue that might happen that can postpone a tamping operation is the seasonal heavy rains. After these heavy rains the surface soil becomes highly saturated and as a result the DC operation would be interrupted as discussed in the previous section. Based on the weather forecast report the predicted delay was considered in the project plan and furthermore since it was based on tamping quantity and not the energy, the delay that might occur in different phases and even in phases themselves were considered.

7. The provision of new Machineries

Based on the investigation that was done there was a great shortage in cranes used for DC operation. As a result of alteration in DC patterns that had a higher energy (about twice) than the former and also delay that had occurred, more cranes needed to be added in site immediately. It was calculated that if the operation would be continued with existing cranes it would need 17 months to be completed. In the calculations the number of drops was considered to obtain the exact capacity and tampers needed in the site. With regard to proposed patterns, it was calculated that by adding 2 high-capacity cranes with an automatic drop system the required time would decrease to 9 months. The contractor's cranes were somehow depreciated except one, and their efficiency for the remaining part of the project was really in question. The contractor was obliged to add one more crane in addition to prescribed compensatory cranes for the cases that the existing cranes are wrecked or need overhaul. Since the compensatory action plan should be followed accordingly, no unexpected cut as a result of field machineries was not acceptable at all. In the coastal south part of Iran with very hot summers, the crane's wreckage would be increased considerably and the overhaul period should be shortened to avoid complete crane failures. The selection of the cranes with automatic drop system was that they have much higher efficiency (about twice) compared to common cranes that existed on site. Although the rent price is higher than the common ones, since there was a high delay in the project the contractor was obliged to provide the cranes with an automatic drop system. One important matter that should be considered regarding these cranes is that because of a special mechanical system that is engineered in the crane the chains are connected during the free fall. The connection of multiple chain lines proportionally reduced impact velocity, increased friction, and consequently reduced impact energy, efficiency and depth of improvement [11]. This connection would dissipate about 10 percent of the energy (based on the technical question answered by the manufacturer) that should be accounted for in designation of the DC or DR patterns.

8. Conclusion

A coastal soil exploitation project was introduced and a summary of the obstacles faced in the project was stated. Because of the high delay that occurred, the project was investigated in detail by the client and consultant technical team. Based on the investigation a compensatory action plan was proposed. The main factors that were considered in developing a compensatory action plan during the revision of the time schedule was discussed. Since in the process of the first time schedule these factors were ignored, a new trend was applied. Based on the extensive investigations, tamping quantity was considered as the main determinative factor. The outline of the influencing factors was 1) the alteration of the exploitation soil comprising a 50-50 percent of former borrow area and the new borrow area which had the required engineered specifications 2) a new pattern for DC was proposed and the height and weight has increased. In the compensatory action plan this matter was considered based on the selected pattern by application of total drop quantity to gain a realistic prediction for the schedule plan. The simultaneous pilot test time was also considered in the compensatory action plan. 3) As a result of the existence of fine-grained soil in the mix, the time needed for dissipation of excess pore water pressure due to the heavy tamping or heavy seasonal rain between 3 phases and even in each phase alone (especially in coastal line) as a function of tamper quantity. it should be noted that by consideration of tamping energy the complexity of the prescribed situation couldn’t be accounted for. 4) The mobilization of cranes between tamping points linked with tampers quantity based on the DC phases and the optimization procedure was accomplished 5) The deficiency of cranes was calculated in accordance with compensatory action plan and the contractor was obliged for provision of cranes with automatic drop system to meet the requirement of compensatory action plan. Since all of these factors’ functionality can be linked to tamping quantity, it is found that this trend can be a satisfactory way for consideration of parameters with high complexity which can delay the project and also as a useful measure for compensatory action plan.

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