Development of a Crawler Type Soil Mixing Machine with Dryer Function

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ABSTRACT:
This paper describes a newly developed soil mixing machine with dryer function. Regarding the core embankment of rock-fill dams, fine-grained soil and coarse-grained gravel must be mixed uniformly and efficiently in the stockpile. When the fine-grained soil is relatively wet, compared to optimum water content, blended soil becomes difficult to be mixed uniformly because fine-grained soil tends to become what is called “clay lumps”. Therefore reducing water content of fine-grained and wet soils is an important issue for the improvement of core quality.
In this background, we developed a machine called “Mantis”, which can blend fine-grained soil and coarse-grained material efficiently even though the mix has a very high content of fines and water. We used a crawler type soil mixing machine, called “Stabilizer” which was improved with a fan for sending hot air produced with engine’s exhausted heat. Finally, we carried out a trial blending test at the stock yard. We found that the processed material was well mixed and its water content was reduced.

Keywords: Fill dam, Core material, Fine-grained Soil, High water content, Stabilizer

1. GENERAL INSTRUCTIONS

Regarding the core embankment of rock-fill dams, when single material does not comply with the specifications, we use two types of material and mix them. Then fine-grained soil and coarse-grained gravel must be mixed uniformly and efficiently in the stockpile. Generally, each material is piled by layers and then mixed by bulldozer. This method is called “Slice cut”.

When the fine-grained soil has high content of water, fine-grained soil becomes difficult to be mixed uniformly, because it becomes what is called “clay lumps”. “Clay lumps” has a diameter between 5 cm and 15 cm and affects the impermeable quality and performance of core. "Clay lumps" portion has excessive content of water. Even if leaving such kind of material under the sun for a long time, the water ratio does not change easily.

In this background, we developed a machine which can blend fine-grained soil and coarse-grained material efficiently even when the mix has a very high content of fines and water. The base machine is “Stabilizer”, employed currently in dam construction with the same problem in core material (Japan Dam Foundation 2009). We named the developed machine “Mantis” because it resembled the insect. Mantis was developed considering carbon dioxide emissions reduction and cost. It has the following features:

(1) Structure is simple because heat sources is engine’s exhausted heat.
(2) Using engine’s exhausted heat is environmentally friendly because it does not increase carbon dioxide emission.
(3) Running cost is low because it uses engine’s exhausted heat.
(4) Because the base machine is stabilizer, it can mix soil well.

To check the functions mentioned above, we carried out trial blending by using the developed machine as shown in Fig. 1.

2. TRIAL BLENDING

2.1. Summary of the trial

On-site trial was conducted in the stock yard of the zoned earth fill dam project. In the stock piles of the stock yard, fine-grained soil and coarse-grained soil were stacked in layers. Fine-grained soil is consist of volcanic ash cohesive soil, natural water content and optimum water content are approximately 90% and 63% respectively, and fine fraction content is approximately 85%. Coarse-grained soil is consist of weathered rock and gravelly soil, natural water content is approximately 10%, and fine fraction content is approximately 12%.

Two cases were conducted in the trial blending: Case 1 was using “Mantis” without drier function and Case 2 was using “Mantis” with drier function. In each case, “Mantis” was operated on the stock piles with 15m length. During the trial blending, we obtained the data every 5times of traveling, namely at 0, 5, 10, and 20 times. Before starting the trial blending, the “Mantis” without using dry function mixed fine-grained soil and coarse-grained soil by a single traveling. Schematic image of the trial blending is shown in Fig. 2.

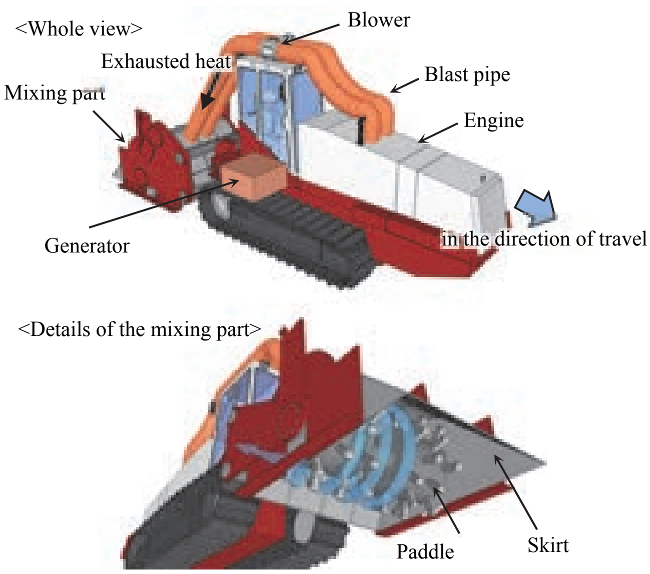

Figure 1. Images of “Mantis”

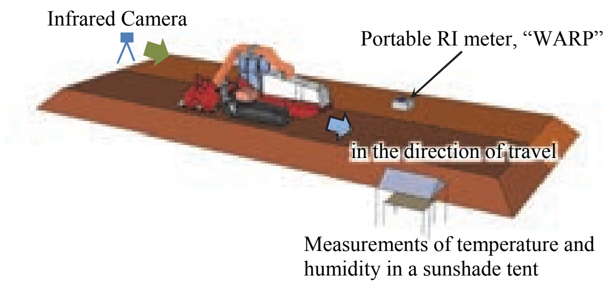

Figure 2. Schematic image of the trial blending

2.2. Specifications of the Stabilizer

The side view of the Stabilizer and the specification are respectively shown in Fig. 3 and Table 1.

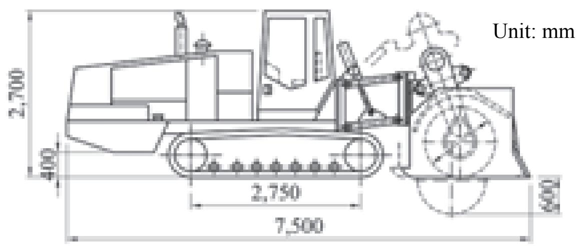

Figure 3. Side view of the Stabilizer

Table 1. Specification of the Stabilizer

Type	STB210C (Toyo Stabi Co., Ltd.)
Length	7.5 m
Width	2.85 m
Height	2.7 m
Mixing width	1.8 m
Mixing depth	0.5 m (Max 0.6 m)
Rated power	151.5 kW(206 PS)、2,200 rpm
Speed of rotation	60～100 rpm (Max 135 rpm)
Running speed (Reference)	Operation : Approx. 2 km/h Moving : Approx.10km/h

2.3. Controlled Data and Equipment

Data types and its specification are shown in this sub-section.

2.3.1. Temperature and Humidity

Atmospheric temperature and humidity were measured with a thermometer and hygrometer indicator. Intentionally, measurement was conducted inside a sunshade tent in order to prevent direct sunlight effects.

The specifications and the picture of this indicator are shown in Table 2 and Fig. 4, respectively.

Table 2. The specification of thermometer and hygrometer indicator

Name	thermometer and hygrometer indicator
Type	LR5001 (HIOKI Co., Ltd)
Range	-40.0 °C～+ 85.0 °C
Accuracy	±0.5 °C

Figure 4. Thermometer and hygrometer indicator

2.3.2. Water Content of Soils (RI Method)

Water content of soil was measured by Simplified Radio Isotope Moisture Meter (Portable RI meter, “WARP”). This new equipment is able to measure water content of soil easily compared to the conventional RI equipment; additionally it is small and light.

Measurements were conducted after smoothing the soil surface, and then data of water content were taken after 0, 5, 10, and 20 times of traveling by “Mantis”. We took the average of 3 data points as a representative data of water content. Specifications of “WARP” and its figure are shown in Table 3 and Fig. 5, respectively.

Table 3. Specification of Radio Isotope moisture meter (Portable RI meter, "WARP")

Type	Neutron Disperse Type (Soil & Rock Co., Ltd)
Detector	^{3}He Proportional counter
Radiation source	Californium 252 1.11MBq
Range	Water content : 0～100%
Measurement depth	10 cm
Measuring time	1 min
Service temperature	0～50 °C

Figure 5. Portable RI meter, "WARP"

2.3.3. Surface Temperature of Soils and "Mantis"

In order to check the effect or the heating system, the surface temperature of soils and "Mantis" was measured by infrared camera.

Specifications of the infrared camera and its figure are shown in Table 4 and Fig. 6, respectively.

Table 4. Specification of infrared camera

Name	Thermo-shot
Type	F-30S (Japan Abionics Co., Ltd)
Range	- 20～100 °C.
Accuracy	± 2 °C.

Figure 6. Infrared Camera

2.3.4. Observation of soils sticking to the mixing paddle

Cohesive soil is easy to stick to the mixing paddle, and reduces the efficiency. In order to check the ability of anti-accretion by "Mantis", mixing paddle was observed by digital camera at each operating time.

2.4. Photographs of Trial Blending

Trial blending was carried out at the rock fill dam project site in Fukushima on the 13th October 2015. Photographs of the trial blending are shown in Fig. 7 to Fig. 9.

Figure 7. Operating "Mantis" (close range view)

Figure 8. Operating "Mantis" (distant view)

Figure 9. Measurement of water content by "WARP"

3. RESULTS

3.1. Temperature and Humidity

During Case 1 (without using drier function), weather was fine, temperature was between 17 and 20 °C around 10:30 AM., and the humidity was approximately 60 %. However, during Case 2 (using drier function) weather was changing suddenly, with some drizzle and strong wind. Temperature dropped and was between 15 and 18 °C (11:18-11:33 A.M.). Ambient temperature and humidity at the trial site is shown in Fig. 10.

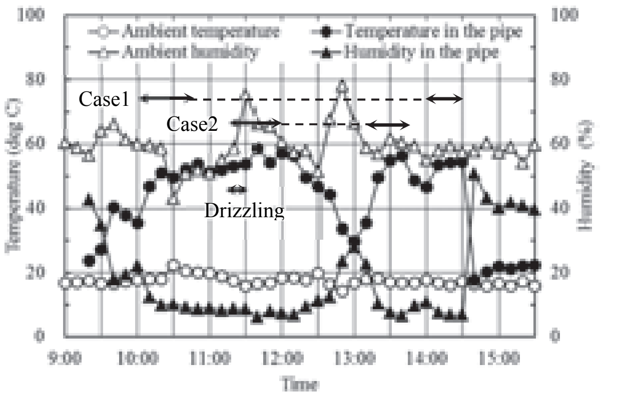

Figure 10. Atmospheric temperature and humidity

3.2. Thermo-graphic Images by Infrared Camera

Infrared camera and digital camera were set in parallel. Thermo-graphic and visible images could be compared during the trial.

The surface temperatures obtained from thermo-graphic image in the side (Fig. 11) were 97.3 °C at engine part, 47.0 °C at blast pipe entrance point, 42.9 °C at blast pipe intermediate point and 41.7 °C at blast pipe discharge point. It is found that the temperature in the blast pipe is gradually falling down toward the mixing part.

The surface temperatures obtained from thermo-graphic image in the mixing part (Fig. 12) were between 20 and 23 °C at skirt of mixing part and from 18.9 to 19.7 °C at surface of the soil.

Since ambient temperature was between 15 and 18 °C, we could estimate that an increment of 2 - 4 °C was caused by heat supplied to the soil by “Mantis”.

3.3. Water Content of Soils

Results of water content of soils by portable RI meter, “WARP” are shown in Table 5 and Fig. 13 respectively. Water decreasing rate defines that subtracting the water content at the running times “0” from “N”.

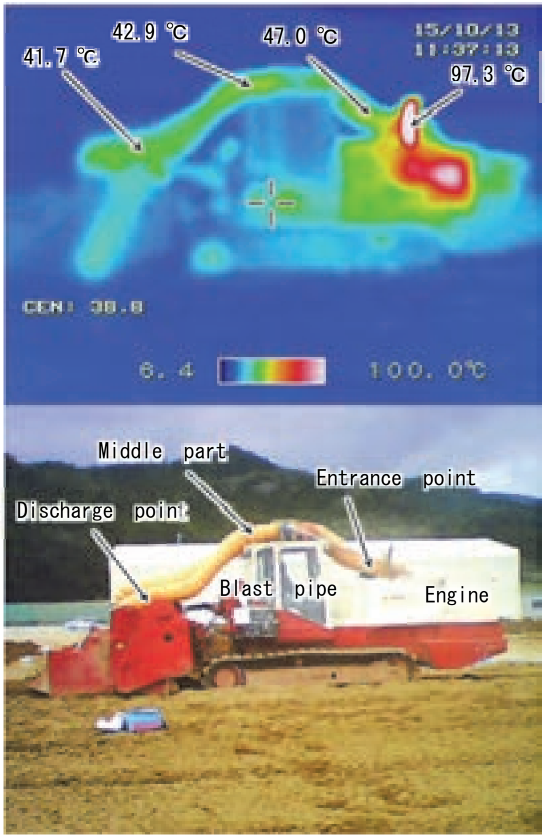

Figure 11. Thermo-graphic image (Whole side)

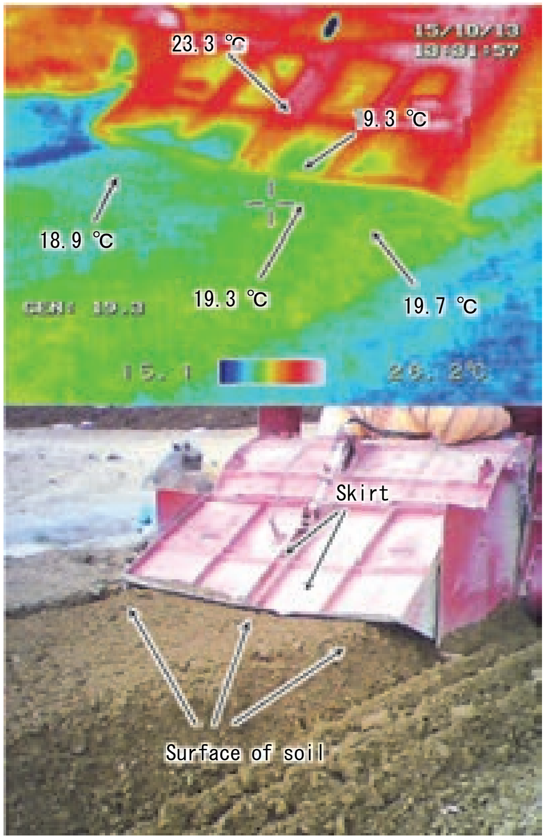

Figure 12. Thermo-graphic image (Mixing Part)

Results show that water degreasing rate at 10 times of running in Case 1 (without using drier function) is 7.8%, and Case 2 (using drier function) is 11.7%. The difference between Case 1 and Case 2 is 3.9%. On the other hand, water decreasing rate at 20 times of running in Case 1 is 12.5%, and Case 2 is 15.4%. The difference between Case 1 and Case 2 is 2.8%.

We found that introducing the stabilizer to blend the soil material in the stockpile was very effective. However, introducing drier function to the stabilizer was more effective to reduce the water content of soils by supplying heat to the soil.

Table 5. Results of water content by "WARP"

Numpers of times of traveling	Water content W1 (%)		Reduction of moisture content W2 (%)		Difference W3 (%)
	Case 1	Case 2	Case 1	Case 2	
0	29.9	35.8	0.0	0.0	0.0
5	23.6	31.2	-6.4	-4.6	-1.8
10	22.1	24.1	-7.8	-11.7	3.9
20	17.4	20.4	-12.5	-15.4	2.8

W1: Average of data at 3 points
W2: W1 minus W1 (at 0 times)
W3: W2 (without dry function minus with dry function)

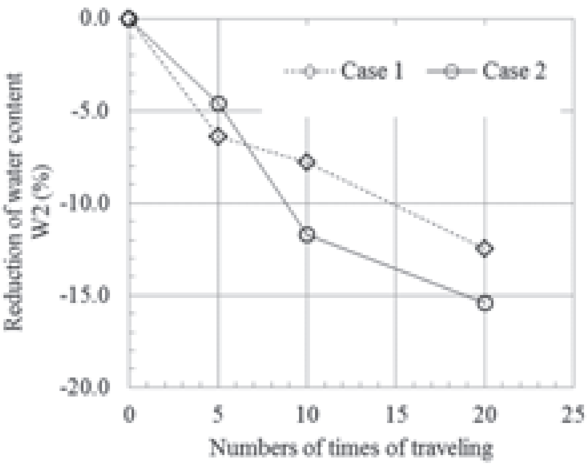

Figure 13. Reduction of water content

3.4. Observation of the Mixing Paddle

Observation of Case 1 and Case 2 could not find a relevant differential. Both of them show almost no soil was sticking to the paddle. It was considered that the water content of soil was relatively low and therefore difficult to stick the paddle.

(1) Case 1 (without using drier function)

(2) Case 2 (using drier function)

Figure 14. Observation of the Mixing Paddle

4. CONCLUSION

In order to dry soil environmentally friendly and economically, we developed "Mantis" by renovating the conventional stabilizer.

Thermo-graphic at the trial showed the blow air temperature was reached to more than 40 °C, and supply heat from 2 to 4 °C to the soil when ambient temperature was from 15 to 18 °C.

Water degreasing rate increased in from 3% to 4% by using dry function when running time was from 10 to 20 times.

Results showed that new developed "Mantis" could dry wet soils effectively for core materials of fill dams.

REFERENCES

Japan Dam Foundation Committee on Construction Technology . (2009): Construction of Fill Dam, Japan Dam Foundation, in Japanese.