The Relation Between Strength of Ground Improvement and P-Wave Velocity when Using the Jumbo-Jet Special Grouting Method

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THE RELATION BETWEEN STRENGTH OF GROUND IMPROVEMENT AND P-WAVE VELOCITY WHEN USING THE JUMBO-JET SPECIAL GROUTING METHOD

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Abstract

Shield construction works are the most popular method employed at the Taiwan Mass Rapid Transit project and underground sewage projects. Joining of the shaft and the tunnel is generally high-risk work because of potential dangers, such as ground collapse and tunnel breaks. Accordingly, we measured the strength of geological improvement at the shield shaft and its P-wave velocities using a boring core and test piece. The test results show that the relationship between the unconfined compressive strength and P-wave velocities is very close. P-wave velocities can be used to estimate density. P-wave velocities will probably become a quality control test yardstick in future.

1. Introduction

The surrounding auxiliary work of starting and arrival vertical shafts, or a cross-passage should use the Jumbo-Jet Special Grouting method, and in order to avoid the effect of shield machine excavation, while its strength should be adequate it also should not be too high. This research used Kaohsiung Mass Rapid Transit shield shaft and cross-passage core samples, and the laboratory simulation tests to measure their corresponding P-Wave velocities and compressive strength. The relation of P-Wave velocities and compressive strength was established, based on the velocity data obtained, so that the quality of the geological improvement could be estimated and provided to the industry for engineering reference.

2. Experiment

2.1 Laboratory testing of mix proportions

We measured unconfined compressive strength against P-wave velocity. Their mix proportions were as follows.

Type A: water + cement, W/C = 0.485 (where, W: amount of water, C: amount of cement)
Type B: water + cement + test sand, W/C = 0.485, cement:sand = 7:3 (by weight)

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2.2 Laboratory test specimen and testing procedure

2.2.1 Unconfined compressive strength test

We constructed 5x5x5 cm cube specimens to be used in the unconfined compressive strength test.

At 3, 7, 28, 91 and 180 days of age, unconfined compressive strength tests are performed. At every age, we tested three test pieces, so that each mix proportion provides 15 test pieces. With 2 mix proportions, the total becomes 15x2 = 30 pieces.

2.2.2 P-wave velocity test

We constructed the test pieces D = 5cm, H = 10cm to be used in the P-wave velocity tests.

At 3, 7, 28, 91 and 180 days, P-wave velocity tests are performed, so that each mix proportion has 5 test pieces, and the 2 mix proportions have a total of 10 pieces.

2.3 In-site core sample test

At the Kaohsiung Mass Rapid Transit project site, where Jumbo-Jet Special Grouting geological improvement work is being carried out, 35 samples were taken at the improvement pile overlapping location, with each group consisting of three 10x5 cm cylinders from the top, middle and bottom sections. P-wave velocity tests were then conducted on those core samples, after which unconfined compressive strength tests, were performed.

3. Relation between Unconfined Strength and P-wave Velocity

3.1 Laboratory testing

Figure 1 shows that the strength of both cement paste and mortar increases with age. The unconfined compressive strength of mortar is stronger than that of cement paste. The relation between age and unconfined compressive strength is linear with a great relative coefficient.

Figure 2 shows that, with both the cement paste and the mortar, P-wave velocity increases with age. The P-wave velocities of mortar are faster than those of cement paste. The relation between unconfined compressive strength and P-wave velocity is linear with a great relative coefficient, which could be represented as formula (1).

$$V_p = \mathrm{A} + \mathrm{B} \times q_u \quad (1)$$

Where V_p : P-wave velocity, q_u : unconfined compressive strength.

The B value is defined as the rate of increase of P-wave velocity. Cement paste has a B value of 1.403, higher than that of mortar, due to the fact that the cement paste consists of thinner and higher density particles.

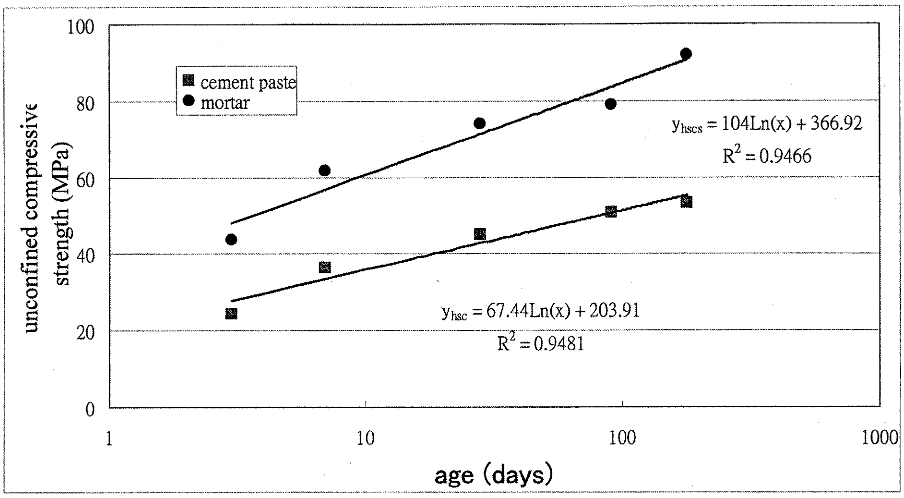

Fig.1 Unconfined compressive strength versus age

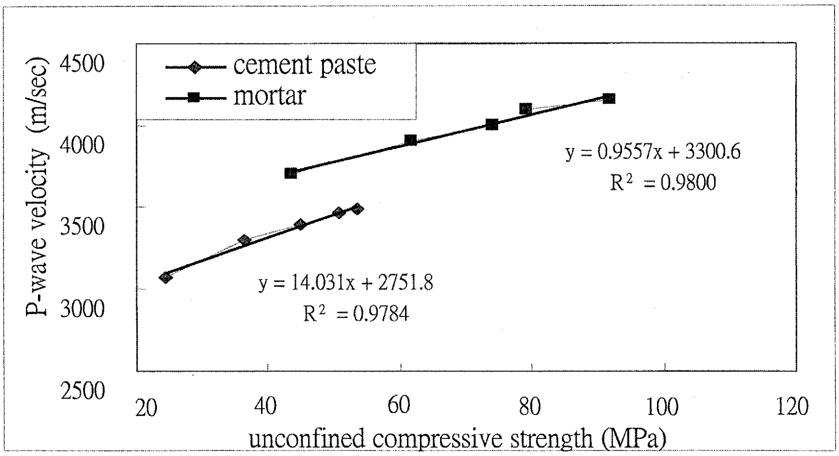

Fig.2 Unconfined compressive strength versus P-wave velocity (indoor laboratory samples)

3.2 In-site core sample test

Figure 3 shows core samples of top, middle and bottom sections from site 1, and the relation between their unconfined compressive strength and P-wave velocity. This relation is similar to that found in the indoor laboratory test results is linear with a great relative coefficient. Using top, middle and bottom section samples from each of the 35 specimens results in a total of 105 core samples, the relation between unconfined compressive strength and P-wave velocity can be represented as formula (2).

$$V_p=2453+3.423\times q_u \quad (2)$$

If we use the depth as parameter, we may divide GL-10-35m into 5 subdivisions in order

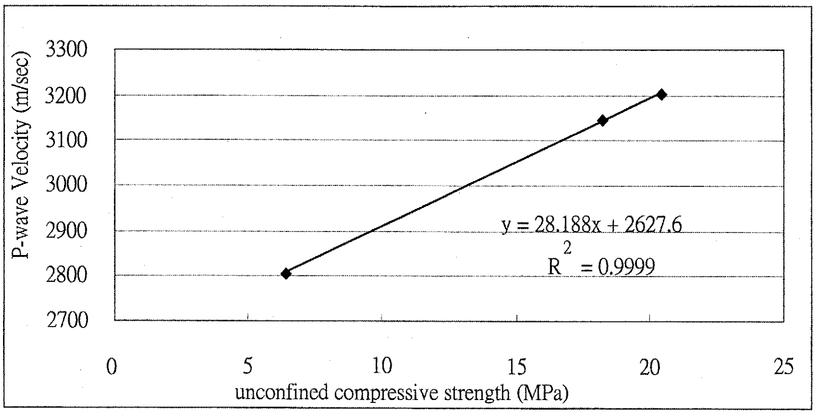

Fig.3 Unconfined compressive strength versus P-wave velocity (on-site core samples)

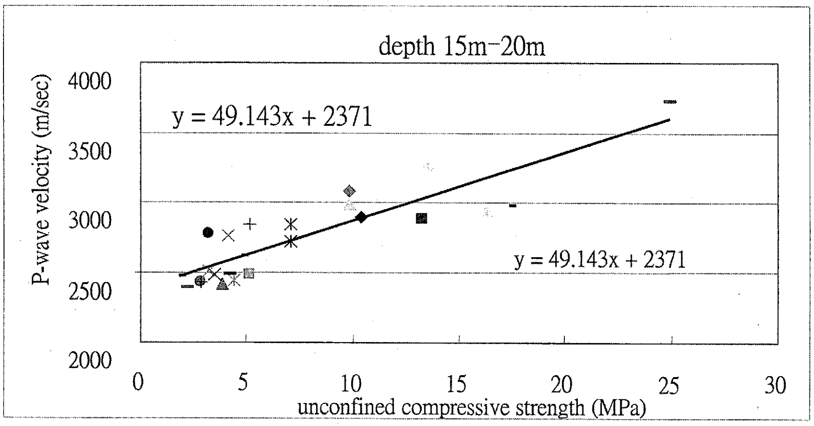

Fig.4 Unconfined compressive strength versus P-wave velocity (on-site core samples taken at a depth of 15m-20m)

to see the relation between unconfined compressive strength and P-wave velocity Figure 4 illustrates site 1. From Figure 4, we can see the linear relation maintained for unconfined compressive strength versus P-wave velocity, revealed in formula (1). Table 1 depicts the intercept (A) and the slope (B) values of those five subdivisions[1].

A is the geological improvement stress release, its relative value with respect to the void among particles. B represents the void congestion speed under stress. From Table 1, we note that the value decreases with depth. On the other hand, the B value increases with depth. This accounts for phenomenon by which the deeper one goes, the greater the amount of void and the weaker the unconfined compressive strength is. The void congestion speed thus becomes higher, resulting in higher P-wave velocities. In order to verify the quantity of such voids, on site core samples should go under an effective void ratio test. At the site 1, during the top, middle and bottom sampling, the depth versus effective void ratio relation is shown in Figure 5. It shows cleanly that the effective void ratio gets worse as the depth increases. Thus we conclude that the effective void ratio is bigger the deeper the geological improvement area is, and quality suffers.

Table 1. The intercept (A) and slope (B) of the V_p curves versus q_u

depth(m)	A	B
10～15	2650	2.821
15～20	2371	4.914
20～25	2331	5.282
25～30	2148	6.338
30～35	2115	7.056

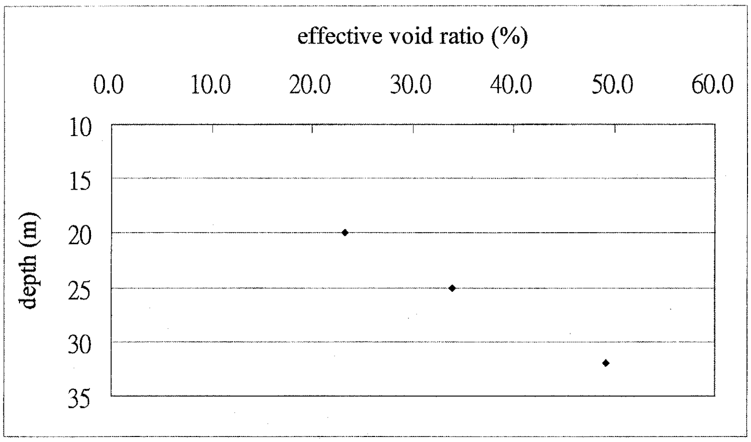

Fig.5 The depth versus effective void ratio

4. Conclusions

From the above test results analysis, we can conclude that

(1) With both cement paste and mortar, in an unconfined compressive strength test, when the age versus unconfined compressive strength is plotted, it is linear. This indicates that both the cement paste and the mortar gain in strength with increase in age.

(2) Using both laboratory mix proportion design test pieces and on-site core samples, the relation between unconfined compressive strength and P-wave velocity is a linear one with great relative coefficient value.

(3) The mortar testing specimens in the laboratory had higher P-wave velocities than those of the cement paste, due to the fact that the cement paste consists of thinner particles of higher density.

(4) In-site core samples show that the effective void ratio gets worse as depth increases. This was estimated from the rate increase of the P-wave velocities.

(5) For shield shaft geological improvement, unconfined compressive strength has a lower limit of 2 MPa. Despite the frequency of voids, this limit is relative easy to achieve. Thus the unconfined compressive strength alone cannot accurately reveal the true quality. Combining both unconfined compressive strength test and P-wave velocity test, it

becomes possible to estimate the void numbers and the density level of the geological improvement, so that an accurate test of geological improvement quality could be performed.

References

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