A COMPARISON STUDY OF TWO ION-EXCHANGE RESIN MIXED GROUTS: CHLORIDE ABSORPTION, STRENGTH AND FRESH PROPERTIES

Saitama University Student Member ○Nguyen Thi Loan
Saitama University Fellow Member Hiroshi Mutsuyoshi
Saitama University Regular Member Yao Luan
Saitama University Student Member Koki Imamura

1. INTRODUCTION

In Japan, since long time pre-stressed concrete bridges are suffering from durability problems, especially those at coastal regions. One of the main reasons causing durability problem is the corrosion of post-tensioned tendons due to chloride attack, especially in case of no grout or partially grouted tendon sheaths. Those corroded tendons require proper repairing and re-grouting. In previous research, a repair material has been developed by mixing ion-exchange resin (IER) into cement mortar to repair concrete structure deteriorated by chloride attack, which effectively absorbs chloride ions from existing corroded structures and alleviates the corrosion afterward[1]. In the present study, based on the similar concept, the authors has made a new repair grout by mixing IER with premix type ultra-low viscosity grout powder, in order to re-grout the duct and remove chloride at the surface of tendon. Two types of IER, namely Gel type and Macro Reticular (MR) type, were used and both types have been comparatively analyzed to fully understand their chloride ion absorption capability, and other properties such as strength, fluidity and bleeding rate.

2. MATERIAL AND EXPERIMENT PROGRAM

IER – IERs are polymers normally in the form of small granules with a diameter of about 0.5-1mm. It has the capability of trapping particular ions in a solution with concomitant releasing other ions. In this research, the strong type anion IERs are used, and when the IER is contacted with chloride ions the following ion-exchange process occurs:

$R\text{-}CH_2N(CH_3)OH + Cl^- = R\text{-}CH_2N(CH_3)Cl + OH^-$

Accordingly, chloride ions in pore solution of grout can be exchanged, decreasing the amount of free chloride ions. The OH- ions released are beneficial to sustain the alkaline environment. *Figure-1* shows the microstructures of the two types of the IER used in this study. Compared with Gel Type, apparently MR Type is more porous, which implies higher surface area and a faster speed of ion exchange.

Gel Type (homogeneous structure) MR Type (porous structure)

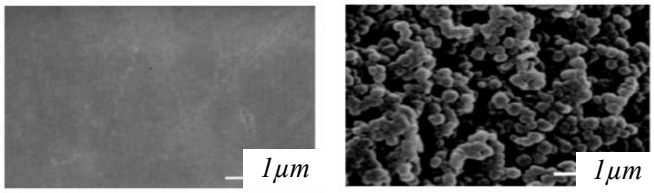

Figure-1 Surface Scanning Electron Microscope photograph

TEST METHOD – Based on JSCE standards[2], fluidity test, compressive strength test, and bleeding test were carried out. The mix proportions of grout, with 3% IER and different water to grout powder ratio (W/P), are shown in *Table 1*.

Table 1 – Series of mix proportions for fluidity, compressive strength and bleeding rate test

W/P (%)	Type of IER	IER Percentage (%)
41, 43, 45, 47	MR	3%
	Gel	

Table 2 - Mix proportions used in the Chloride ions adsorption test

W/P (%)	Type of IER	IER Percentage (%)	Chloride absorption capacity (kg/m^3)	Actual chloride ions adhesion amount (kg/m^3)
45	MR	3	3.36	3.33
		7	6.86	
	Gel	3	3.36	

In chloride ions adsorption test, after immersion of seven-wire strand in 26% NaCl solution, specimens of size 3cm × 10cm (diameter × length) were cast using pure water, with mix proportions shown in *Table 2*. The IER mixed grout were crushed and grinded into powder, and sieved through fine meshed sieve (149μm) after 1 day, 7 days and 28 days curing, respectively. Then, centrifugation method was used to separate the IER powered and grout powder, which were immersed in the carbon tetrachloride solution. The amount of anions in grout powder was quantitatively analyzed using capillary electrophoresis. On the other hand, the amount of grout adhered to collected IER was determined by the method of Inductively Coupled Plasma (ICP) Atomic Emission Spectrometry.

3. RESULT AND DISCUSSION

The flow time of the grout mixed with MR type, after an elapsed time of zero minute (fluidity test was done immediately after mixing), is smaller than those of gel type, for different W/P ratios *(Figure 2-a)*. However, after an elapsed time of 30 minutes, the grout mixed with MR type has a longer flow time than the corresponding grout mixed with Gel type *(Figure 2-b)*. The reason is that as the surface area of MR type resin is larger than the gel type, it has faster water absorption rate and makes the MR type mixed grout solidified within shorter period.

Keywords: Ion-exchange Resin, Grout, Chloride absorption, Strength, Fluidity, Bleeding Rate
Contact address: Saitama University 255, Shimo-Okubo, Sakura-ku, Saitama, 338-8570, Japan, Tel: 048-858-3565

In compressive strength test, the 7 days strength of MR type mixed grout specimens are 10-20% higher than those of the specimens with gel type, for all of W/P ratios *(Figure 3)*.
In bleeding rate test, it was found that after 3 hours, gel type mixed grout has bleeding rate higher than those with MR type *(Figure 4)*, but no bleeding was observed after 24 hours for both types of IERs.
It is pertinent to mention here that all three tests were conducted by conforming the standard limits of JSCE i.e. flow time in cone of standard size ≤14 seconds, 7 days compressive strength ≥ 30 MPa, bleeding rate ≤ 0.3%.

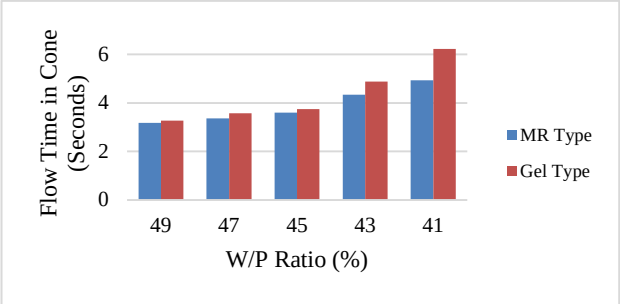

Figure 2-a Fluidity of Grouts mixed with IER - MR Type & Gel Type-3% (0 minutes after mixing)

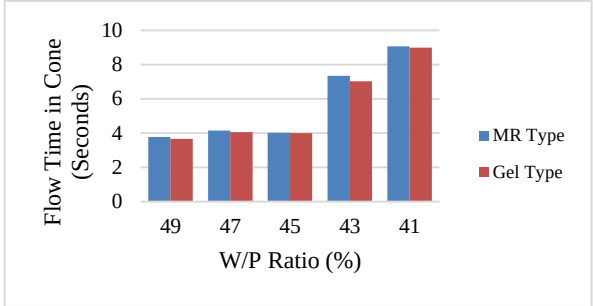

Figure 2-b Fluidity of Grouts mixed with IER - MR Type & Gel Type-3% (30 minutes after mixing)

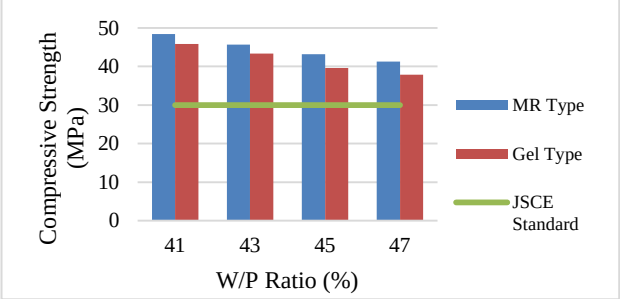

Figure 3-Compressive strength of IER - MR Type & Gel Type-3%

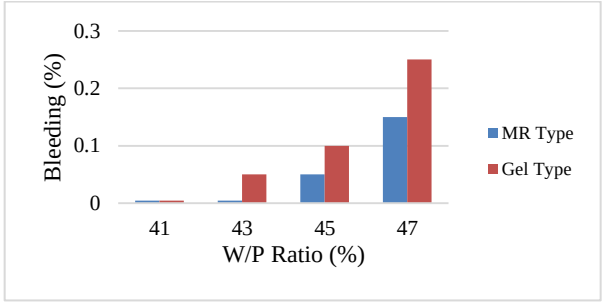

Figure 4-Bleeding Rate of IER - MR Type & Gel Type-3%

In chloride ion absorption test, IERs of strong bases has an order of anion absorption as SO_4^{2-}>NO_3^->Cl^-. The concentrations of SO_4^{2-}, NO_3^- and Cl^- were analyzed using capillary electrophoresis. The result showed that Cl^- occupied an overwhelming portion of anions, whereas the ions of SO_4^{2-}, NO_3^- are smaller than 50 mg/L (the minimum measurable value).
It means that chloride ions absorption capacity of IERs in grout appears not to be significantly influenced by SO_4^{2-}, NO_3^-. Furthermore, environment in sheath is far from an aqueous environment, so the absorption order as mentioned above (SO_4^{2-}>NO_3^->Cl^-) may not be practicable. By assuming the amount of SO_4^{2-}, NO_3^- negligible and using ICP test result, the amount of chloride ions absorbed by IERs were calculated and shown in *Figure-5*. The graph depicts that the amount of chloride ions absorption increases with rise in percentage of IER mix proportions. In addition, the amount of chloride ions absorption for MR type is also higher than that of gel type resin. However, the reason for the phenomena that the decrease in amount of chloride ions with the elapsed of time (specimen age) is still unclear.

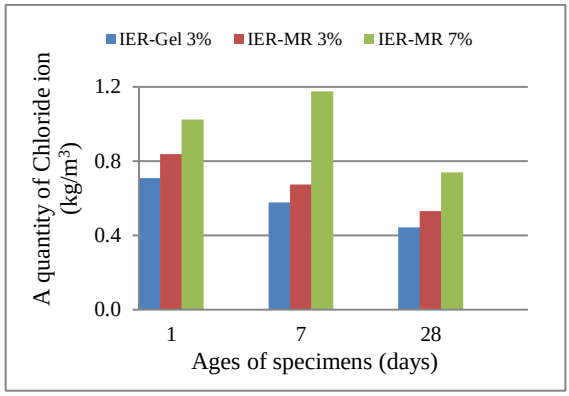

Figure-5 A quantity of Chloride ions were absorbed by IER in 1m^3 grout

4. CONCLUSION

It is concluded that the MR type resin mixed grout became viscous soon as compared to that mixed with gel type resin. Furthermore, with the same W/P cement ratio, compressive strength of MR type mixed grout is higher than that of gel type mixed grout, while bleeding rate has an opposite trend.
In the chloride absorption test, both grout mixed MR type and gel type has shown a rise in chloride ions absorption capability with the increase of IER mix proportion. Furthermore, MR type has shown a superior chloride ions absorption rate than gel type in the initial period of time and decrease in amount of chloride ions absorption with the elapsed of time (age) is unclear which need to be addressed in future research.

REFERENCES

1. Haque, M. N., Mutsuyoshi, H., Sanada, O. and Inoue, N.: Corrosion resistance potentiality of resin mixed cement concrete, Abstracts of the 68th Annual Symposium of Japan Society of Civil Engineering, 2013
2. Japan Society of Civil Engineering Standard, “Fluidity test method of PC grout”- JSCE-F531-2013,”Test method of compressive strength of PC grout”- JSCE-F531-2012, “Bleeding rate test method of PC grout”-JSCE- F532-1999.