RESEARCH ON THE FATIGUE DURABILITY OF RC SLABS WITH PVA AND EXPANSIVE AGENTS ADDED

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1. INTRODUCTION

Usage of chemical agents to reduce crack occurrence and propagation in concrete members is well known. Due to crack inhibition they seem to be one solution for bridge decks where high durability is of prime importance. The high number of load cycles lead to progressive damage of deck slabs resulting in spalling of bottom concrete and ultimately punching shear failure [1]. The failure mechanism of RC bridge decks has been documented by fatigue tests using the wheel load running machine by Matsui [1].

Expansive agents have the unique ability to provide a volumetric expansion during early setting in order to compensate for plastic and drying shrinkage. Poly vinyl alcohol (hereinafter, PVA) in contrast increases the air void content, apparent fluidity and importantly the bond strength between coarse aggregate and cement matrix [2]. The authors carried out wheel load running tests to investigate the fatigue durability of expansive and PVA concrete slabs and compared their performance under fatigue loading with normal reinforced concrete slabs, made without the addition of crack mitigating chemical agents.

2. EXPERIMENTAL PROCEDURE

The test specimens were models of real bridge slabs. Fig. 1 illustrates the reinforcement details and dimensions of the slab. A general mix design that adheres to manufacturer specifications was used and is given in Table 1. The expansive agent was added in place of equal cement content, whereas PVA was added in place of equal water content in the respective mix.

The loading program was designed using the punching shear load equation for RC slabs [3]. The running load was calculated to be 180kN for the normal RC slab to fail at the predetermined 200,000 loading cycles. The wheel was stopped at predetermined locations along the longitudinal direction and displacement readings along the longitudinal and transverse sections across the slab center recorded under static loading at regular intervals. Strain readings on the top concrete surface as well as of the embedded reinforcement bars were also obtained. Crack occurrences on all surfaces were documented with the corresponding load cycle number.

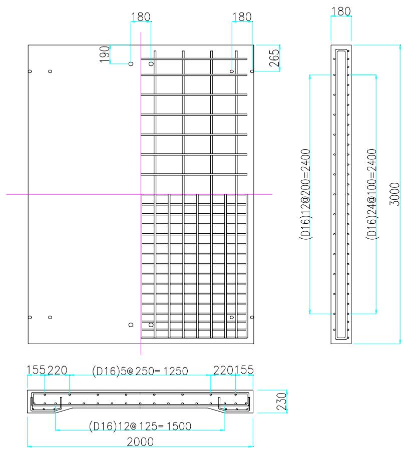

Fig. 1 Slab Details

Table 1 Characteristics of concrete mix

Concrete Type	w/c (%)	s/a (%)	Weight per unit volume (kg/m^3)							Slump (cm)	Air (%)
			Water	Cement	Gravel	Sand	Water reducer	Exp. agent	PVA		
Normal	55	45.9	179	326	979	803	3.26	-	-	16.5	4.5
Expansive	55	45.9	179	306	979	803	3.26	20	-	18.3	5.2
PVA	55	45.9	162.7	326	979	803	3.26	-	16.3	17.5	4.8

3. RESULTS

3.1 Material Tests

Material test results for D16 steel reinforcement bars showed average yield strength of 337 MPa and Young's modulus of 192 GPa. Cylinder tests for compression of concrete were carried out 28 days after casting and before the start of the wheel load running test. The results are shown in Table 2.

Table 2 Material Properties

Concrete Type	Compressive Strength /(MPa)	E /(GPa)	Poison Ratio
Normal	35.32	26.3	0.15
PVA	31.98	23.7	0.18
Expansive	35.42	26.7	0.20

3.2 Fatigue Durability

The normal RC slab failed under punching shear at 59,000 cycles. Although the failure was earlier than the expected 200,000 cycles, the crack development and failure pattern was found to be similar to other normal RC slabs. Tested under running wheel loads, it was found that PVA addition had no significant impact on the fatigue durability. The PVA slab failed at 226,000 cycles under 180kN load.

The expansive concrete slab under the same loading reached 1 million cycles without any tendency to fail, at which point the running load was increased up to 200kN. Under the increased load the slab subsequently failed

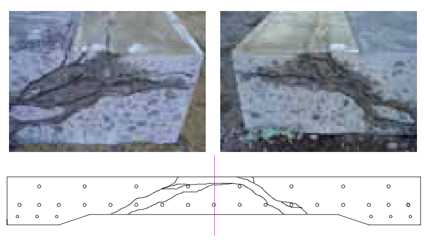
Fig. 2 Punching shear damage

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at 1,310,000 loading cycles. Fig. 2 shows the mid section of the expansive concrete slab after failure. The center displacement of each slab is compared with increasing load cycle number in Fig. 3. The data of the expansive slab are converted to 180kN equivalent load cycles after 1 million cycles. All three slabs appeared to fail under punching shear.

3.3 Crack Occurrence

Prior research have found that nearly half of the cracks that occur in RC slabs under wheel loads appear within the first 5% of cycles from the total number of cycles for failure [4]. The crack patterns at 20,000 cycles are illustrated in Fig. 6. In comparison to the other two slabs, the expansive concrete slab showed very few cracks on the bottom surface. Most of the cracks on the normal RC slab appeared by 20,000 cycles, while the PVA concrete had a similar crack pattern, but less cracks. In the expansive concrete slab crack occurrence was found to be more linear with approximately 80% of the cracks being visible only by 1 million cycles, after which very few new cracks appeared.

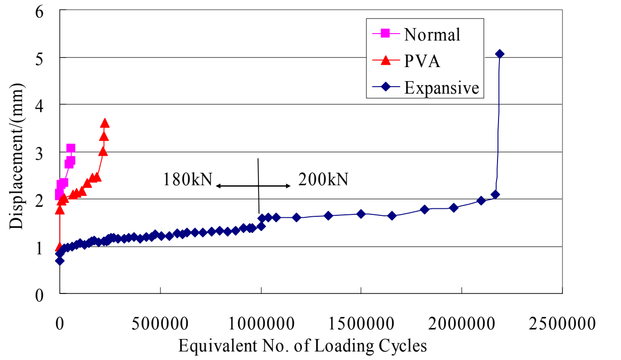
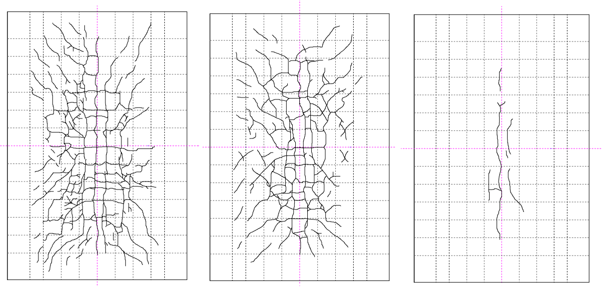


Fig. 3 Live load deflection at center



Normal PVA Expansive

Fig. 4 Crack pattern after 20,000 cycles

4. DISCUSSION

The mechanical material properties show that PVA and expansive concrete are relatively similar to normal concrete and all slabs were seen to fail under the same failure mode when tested with the wheel load running machine. The S-N relation in Fig. 5 show that durability of expansive concrete under fatigue loading is over 10 times greater than the durability of normal RC. The equation in Fig. 5 indicates the S-N relation for normal RC slabs under fatigue loading developed by Matsui [1].

Due to the initial expansion of the expansive concrete a chemical prestrain is introduced on to the reinforcement bars which in turn provide a chemical prestress to the surrounding concrete. This compressive stress offsets the tensile stresses developed during drying shrinkage. This phenomenon is thought to mitigate crack occurrence, especially during early setting period. This is clear by observing the strain occurrence in the reinforcement bars of each slab. The readings obtained from strain gauges attached to reinforcing bars near the slab center are shown in Fig. 6.

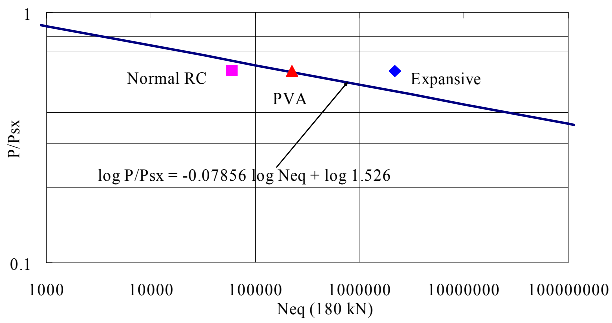


Fig. 5 S-N Comparison

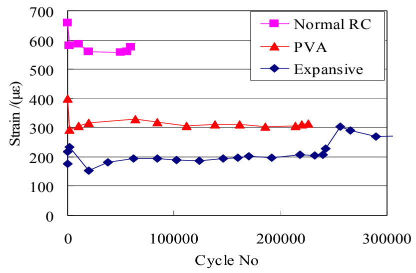


Fig. 6 Bottom main rebar live load strain near slab center

The deflection of a slab is considered as a good indication of its stiffness [4]. The deflection of the expansive concrete slab is found to increase linearly while being smaller than both the normal RC and PVA slabs. The increase in stiffness of the concrete slab can be attributed to the chemical prestress induced by the prestrained reinforcement.

5. CONCLUSIONS

1. The durability of RC with expansive agents added was found to be more than 10 times the durability of normal RC when tested with the wheel load running machine.
2. Addition of PVA had little impact on the fatigue life of concrete deck slabs
3. Expansive agents reduce the occurrence and propagation of fatigue cracks
4. The stiffness of a concrete deck slab is increased by the use of expansive agents resulting in smaller deflections

REFERENCES

[1] Matsui, S., “Life Prediction of Bridges,” Japan Society for Safety Engineering Journal, Vol.30, No.6, 1991, pp. 432-440 (in Japanese)

[2] Kim, J.-H., Robertson R.E. and Naaman, A.E., “Structure and properties of poly(vinyl alcohol)-modified mortar and concrete,” Cement and Concrete Research, Vol.29, 1999, pp. 407-415

[3] Maeda, Y. and Matsui, S., “Punching Shear equation of Reinforced Concrete Slabs,” JSCE, Vol.348/V-1, Aug., 1984, pp.133-141 (in Japanese)

[4] Maeda, Y. and Matsui, S., “A Rational evaluation method for deterioration of Highway Bridge Decks,” JSCE, Vol.374/I-6, Oct., 1986, pp. 419-426 (in Japanese)