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Research paper

An Experimental Study on the Performance Evaluation of Resistance Force and Impact-Sound in Reinforced Concrete Bearing-Wall Reinforced with Composite Mortar

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Abstract

The ultimate object of the study is developing new repair and strengthening method in order to reduce floor noise and improve seismic performance which are required at remodeling construction such as apartment house. Strength performance evaluation is conducted through cyclic behavior at the research of reinforced concrete wall applied composite mortar strengthening method with EVA and EPS. Also, research of impact-sound is conducted in the construction site for H apartment which are reinforced the same method. During the research, the strength performance fo the model reinforced EPS composite mortar is 1.19 times increased in comparison with unreinforced model and the model reinforced EVA composite mortar is 1.44 times increased.

Keywords: *Composite Mortar; Impact-Sound; Reinforced Concrete; Beraing-Wall; EVA; EPS*

1. Introduction

This study has the final objective of securing comfortable living spaces for residents of joint housing by developing a new repair and reinforcement construction method for enhanced earthquake-resistance and the suppression of noise between floors as required upon remodeling buildings, such as joint housing.

This study has performed a performance evaluation on crashing sounds in apartment sites and the evaluation of resistance force in bearing walls that receive repeated loading by developing mortar suitably mixing polystyrene (expanded polystyrene, EPS) and foam rubber (ethylene-vinyl acetate copolymer, EVA) developed as noise-vibration materials.

The evaluation of resistance force performance comprised a production of three reinforced concrete bearing wall specimens with the use of reinforcements, and the use of EPS and EVA reinforcement materials as the variables, an assessment of the final destruction properties, resistance performance, rigidity and malleability performance based on the repeated movement of the specimen, and a comparative analysis of the resistance force using the MIDAS-FEA program. Furthermore, light and heavy crashing sound experiments were performed on a three-level experiment space (H apartment site in Chungju, Chungbuk), where the closing construction has been completed, with the use of reinforcements and reinforcement materials as the variables.

2. Reinforcement Construction Method

Figure 1 displays the order of reinforcements applied in this study. Reinforcements were conducted in the order 「(a) surface grinding→(b) primer application→(c) wire mesh attachment→(d) composite mortar treatment→(e) wall finishing」. The process up to the application of primer was conducted for enhanced attachment of the reinforcement materials. Furthermore, a single reinforcement method was used for the wire mesh without the need to connect both surfaces, and both surface reinforcement was performed with composite mortar. A lattice material having a diameter of 4.2mm was applied as the wire mesh, and anchor bolts with a diameter of 10 mm were used on certain intervals.

EVA and EPS materials were used as reinforcements of composite mortar to suppress noise between floors as displayed in Figure 2, and consistent thicknesses of less than 5 mm were applied. With respect to the ratio of mixing the reinforcement materials, 1% of the entire ratio was added in consideration of the strength of composite mortar through numerous repeated experimentations, and standard cement mortar was used. The total thickness of reinforcement was set as 30 mm in consideration of the minimization of the covered thickness of wire mesh and the weight of reinforcement mortar.

(a) Pre-treatment and application (b) Wire mesh attachment

(c) Composite mortar treatment (d) Surface treatment and finishing

Figure 1: Order of Construction on Specimen

(a) EVA (b) EPS

Figure 2: Appearance of Composite Mortar Reinforcements

3. Resistance Force Performance Evaluation Experiment Plan

Table 1 displays the resistance wall specimens for evaluating the resistance force performance. Three reinforced concrete resistance force specimens were produced with the use of reinforcements and the use of EPS and EVA as reinforcements as the variables.

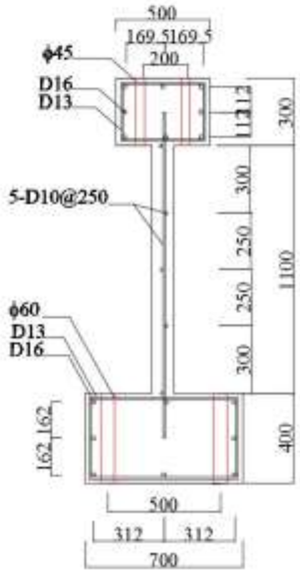
The appearance and dimensions of the produced specimens are displayed on Figure 3. The specimens were reinforced concrete bearing walls with a wall thickness of 100 mm, and section of 1100 x 1100 mm (B x D) by applying the strength design method as regulated by the "Concrete Structure Design Standards (KBC 2012 Design Standards)1)". D10 were used for both the transverse reinforcement and main steels. The vertical reinforcement steel was arranged in 275 mm intervals and the transverse reinforcement steel was arranged in 250 mm intervals. The stub of the upper and lower portions were sufficiently reinforced as not to cause unnecessary destruction using D16 and D13.

Furthermore, the upper stub was buried with a PVC pipe having a diameter of Ø45 to connect with the loading device, and the lower stub was buried with a PVC pipe having a diameter of Ø60 to fix the specimen.

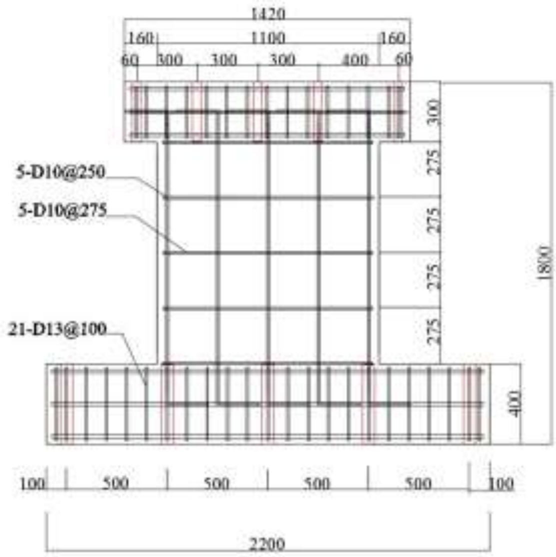
The compressive strength of concrete was configured to be 24 MPa, and the experiment result of the compression strength was displayed to be 26.9 MPa. The yield strength and tensile strength of D10 were 440 MPa and 510 MPa, respectively, and the yield strength and tensile strength of D13 were 455 MPa and 521 MPa, respectively.

Table 1: Specimen list

Specimen	Compressive strength	Reinforcement form	Ratio of reinforcement material	Thickness of specimen	Diameter of wire mesh
	(MPa)		(%)	(mm)	
NONE	24	-	-	-	-
EPS	24	Double sided wall type	1	30	4.2
EVA	24				



(a) Side view of specimen



(b) Plan view of specimen

Figure 3: Shape of specimen

4. Crashing Sound Performance Evaluation Experiment Plan

4.1 Experiment Plan

To evaluate crashing sound performance, a standard light and heavy crashing sound experiment was conducted based on the KS F 2810-1:20152) and KS F 2810-2:20123) standards at H apartment located in Chungju, Chungcheongbuk-do, which framework construction has been finished.

Table 2 displays the details of the experiment for evaluating the crashing sound performance. In a 20-level apartment, the 9th floor was set as the standard floor having no reinforcements, and the 7th and 5th floors were reinforced with composite mortar using the same method as the resistance force specimen.

Figure 4 displays the construction site, sound source room and sound receiving room for the ground crashing sound experiment.

Table 2: Crashing sound performance evaluation

Floor	Reinforcement	Type of reinforcement
9	NONE	-
7	EVA	Wall reinforcement
5	EPS	Wall reinforcement
Note) EVA : Foam rubber		

(a) Construction Site

(b) Sound Source Room (Bang Machine)

(c) Sound Source Room (Tapping Machine)

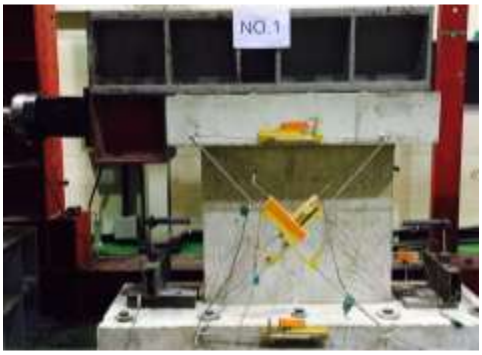
(d) Sound Receiving Room

Figure 4: Crashing sound evaluation site (Chungju H apartment site)

5. Test Result

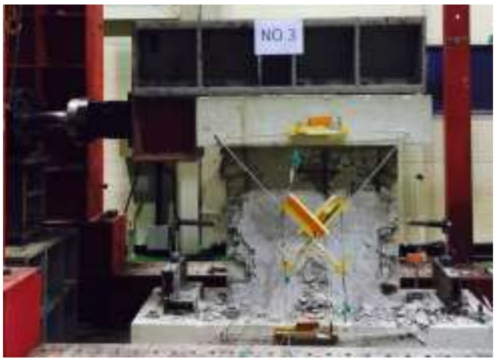
5.1 Final Failure Pattern of Specimen

Shown in Figure 5 is the final failure pattern of each specimen. Specimen No. 1 without reinforcement showed shear cracks to be the dominant pattern, and at the fourth cycle, the displacement after the maximum strength drastically increased. Specimen No. 2 reinforced with EPS composite mortar showed the maximum load of 78.0kN at the 11th cycle with rapid detachment of reinforcement and cracks. And Specimen No. 3 reinforced with EVA composite mortar showed the maximum load at the seventh cycle, and resulted in the final failure with ductile behavior.



(a) NONE

(b) EPS



(c) EVA

Figure 5: Final failure pattern

Figure 6 shows the load-displacement relation of each specimen. And Table 3 shows the resistance force performance evaluation results of the bearing wall specimens. The resistance force of Specimen No. 2 reinforced with EPS composite mortar and Specimen No. 3 reinforced with EVA composite mortar was up to 1.19 and 1.44 times higher than that of Specimen No. 1 without reinforcement.

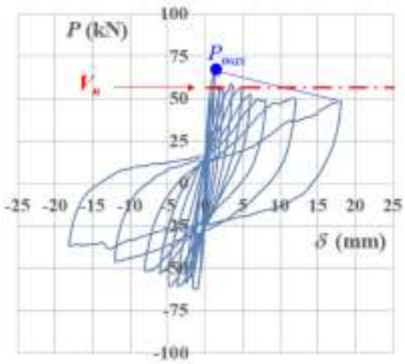
Before conducting the resistance force performance evaluation based on the structural test, the study estimated the resistance force suitable for the displacement by using MIDAS-FEA, a non-linear finite element analysis program.

And the calculated value was based on Eqs. (1) and (2) of Concrete Code by KBC 2012.1)

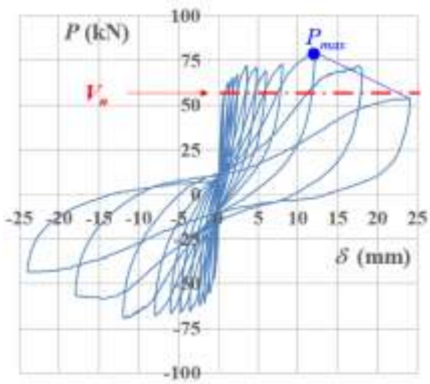
Vu ≤ □□Vn (1)

$$Vn = Vc + Vs \leq (5/6)\,\lambda\sqrt{fck}\,hd \quad (2)$$

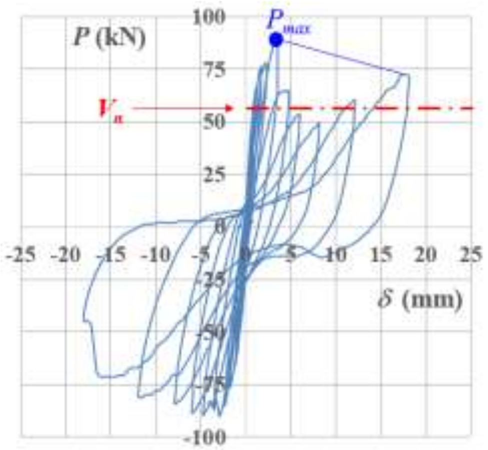
Here, □□is 0.75, Vc is the shearing strength of concrete, Vs is the shearing strength of rebar, h is the thickness of the shear wall, d is the effective depth of the shear wall (0.8 times of the horizontal length of the shear wall lw), □ is the lightweight concrete coefficient.



(a) NONE



(b) EPS



(c) EVA

Figure 6: Load-displacement relation

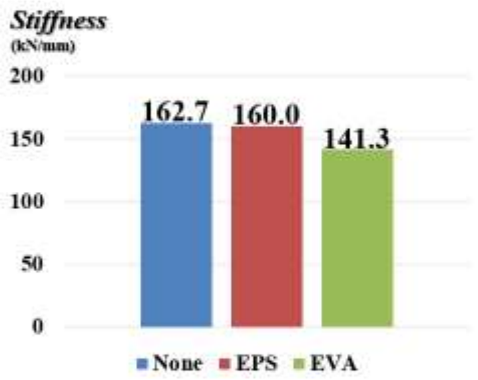
Table 3: Test results

Specimen	Direction	Test result			Analysis value	Calculated value
		P_{max}	$\delta_{max.ave}$	P_{max}	P_{max}	V_n
		(kN)	(mm)	(rate)	(kN)	(kN)
NONE	+	65.6	1.25	-	53.1	55.1
	-	-62.3	-1.05			
EPS	+	78.0	11.99	1.19	-	-
	-	-69.5	-11.76	1.12		-
EVA	+	88.7	3.64	1.35		-
	-	-89.5	-4.82	1.44		-

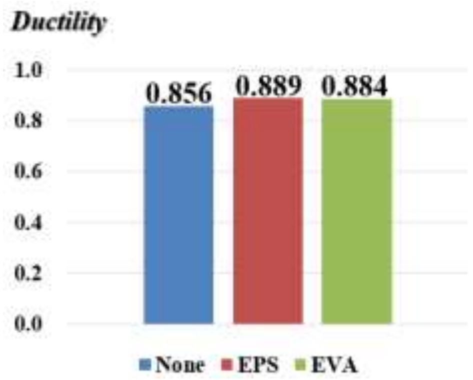
Shown in Figure 7 (a) is the comparison of stiffness by specimen. The evaluation of the ductility capacity was done by Eq. (3), and Figure 7 (b) shows the ductile capacity of each specimen. While there was no significant difference in ductility capacity among the specimens, that of the reinforced specimens was somewhat higher than the others.

□□ = □u / □y (3)

Here, □u is the displacement at failure, and □y is the displacement at deflection.



(a) Stiffness



(b) Ductility

Figure 7: Stiffness and ductility evaluation

5.2 Impact Noise Performance Evaluation

Table 4 show the lightweight and heavyweight impact noise test results. And, Figure 8 and 9 show the frequency-dependent fluctuation of the floor impact noise level in inverse A-weighting based on the standard lightweight and heavyweight impact source. The inverse A-weighting standard curve was calculated as shown in Table 4 based on KS F 2863-1 and KS F 2863-2. If the difference between the maximum sound pressure level and the background noise level is 6dB or low, the measured results were disregard, and by conducting the cyclic test, the reverberation time was compensated from the measured values.

The impact noise performance evaluation showed that compared to the measured value at the ninth floor without reinforcement, the lightweight impact noise measured at the reinforced seventh and fifth floors was reduced equally by 9.5%, and the heavyweight impact noise measured at the EVA-reinforced seventh floor was reduced by 10.0%, and that at the EPS-reinforced fifth floor was reduced by 12.2%.

Table 4: Impact noise performance evaluation result

Floor	Specimen	Lightweight impact noise (dB)	Lightweight impact noise reduction ratio (%)	Heavyweight impact noise (dB)	Heavyweight impact noise reduction ratio (%)
9	None	46	-	55	-
7	EVA	42	9.5	50	10.0
5	EPS	42	9.5	49	12.2

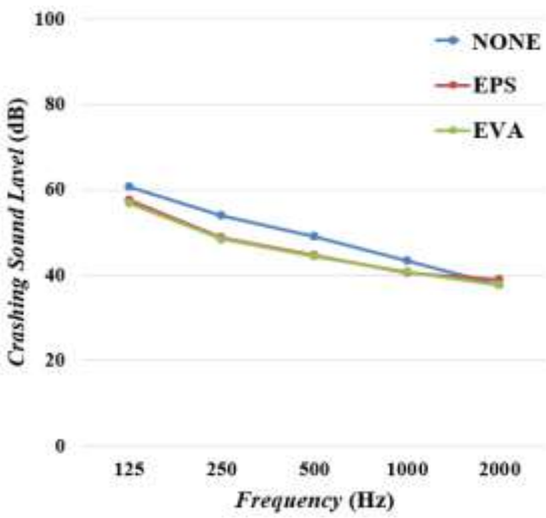


Figure 8: Inverse A-weighting properties (Lightweight impact source)

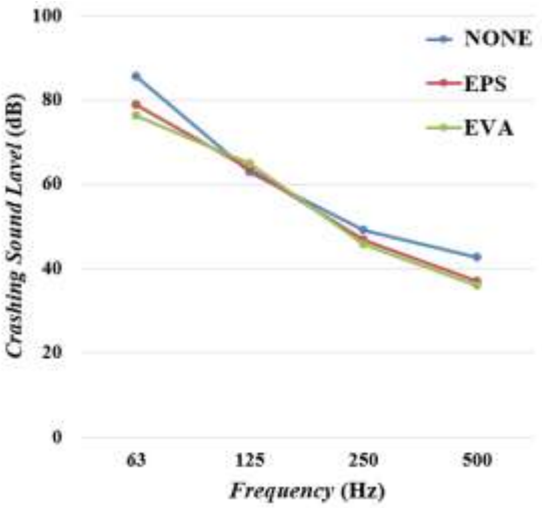


Figure 9: Inverse A-weighting properties (Heavyweight impact source)

6. Conclusions

Based on the previous slab test results, the study conducted the resistance performance evaluation of EVA and EPS composite mortar-reinforced bearing wall. The resistance force of Specimen No. 2 reinforced with EPS composite mortar and Specimen No. 3 reinforced with EVA composite mortar was up to 1.19 and 1.44times higher than that of non-reinforced Specimen No. 1. When applied to the bearing wall reinforcement, the EVA material also showed somewhat superior resistance improvement.

There was no significant difference in stiffness between the non-reinforced and reinforced specimens. This is due to the detachment of reinforcement materials, it is believed that it does not have no marked significance. And, the ductility performance of the reinforced specimens was somewhat higher than that of the non-reinforced specimens.

The study conducted the lightweight and heavyweight impact noise performance evaluation at a construction site for multi-family housing based on KS F 2863-1 and KS F 2863-2. The impact noise performance evaluation showed

that compared to the measured value at the ninth floor without reinforcement, the lightweight impact noise measured at the reinforced seventh and fifth floors was reduced equally by 9.5% and the heavyweight impact noise measured at the EVA-reinforced seventh floor was reduced by 10.0% and that at the EPS-reinforced fifth floor was reduced by 12.2%.

Accordingly, the proposed method offered superior resistance force and impact noise performance to those of the existing methods. However, futher research will be conducted on the bonding performance between the member and composite mortar and fire-resistance performance of composite mortar.

Acknowledgement

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