Research paper

Full scaled–column blast experiments for investigating the influence of the stemming materials on the column fragmentation in explosive demolition

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Abstract

Explosive demolition of structures may cause blowouts, flying rocks, and noise due to shorter length of drilling and stemming, compared to rock blasting. Therefore, stemming plays a very important role in this process, but there have been few studies on the effect of types of stemming materials on blasting efficiency. The study analyzed explosion confinement of selected three stemming materials ; natural sand + crushed stone mixture, non–shrinking grout mortar and white cement mortar, applicable to explosive demolition through single hole blast tests of rectangular and square type columns. It was revealed that non–shrinking grout mortar was highest in blast efficiency and stemming resistance performance in rectangular type columns. Three stemming materials should be applicable to explosive demolition of square type columns which have relatively long stemming length.

Keywords : explosive demolition, stemming, blasting efficiency, rectangular type columns, square type columns

1. Introduction

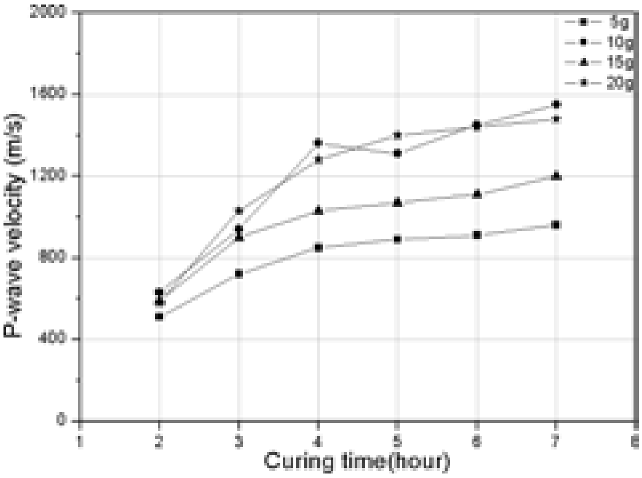
Main stemming material used for explosive demolition of reinforced concrete (RC) is the sand+crushed stone mixture, and the goal of stemming is to increase detonation energy from exploding explosive loaded in blasting hole and in turn to raise fragmentation efficiency and reduce vibration and noise. Accordingly, even though stemming material is an important factor to make explosive demolition a success, there have been few studies on the effect of stemming materials on fragmentation efficiency and reduced vibration based on quantitative analysis, as in open pit rock blasting[1)–3)]. In particular, explosive demolition of structures is designed for columns and load bearing wall, and therefore stemming length is so short that it is hard to contain detonation energy, highly likely to cause blowouts, compared to common blasting. In this case, detonation energy may not be enough to fracture columns or load bearing walls and in turn have an adverse effect on the collapse behavior of the entire structure, possibly leading to the failed explosive demolition.

This study aims to identify the stemming materials applicable to explosive demolition of rectangular and square type columns by examining stemming materials to be applied to explosive demolition. First of all, three stemming materials (natural sand + crushed stone mixture, non–shrinking grout mortar and white cement) were selected from various stemming materials applicable to explosive demolition in consideration of economy, constructivity, and site applicability. Full scaled–columns which have a single blast hole were conducted and fragmented area or damaged volume of blasted columns and collapse speed and flying speed of stemming materials were measured. The collapse speed and flying speed of stemming materials due to detonation load were measured using the dynamic data monitoring system[4), 5)].

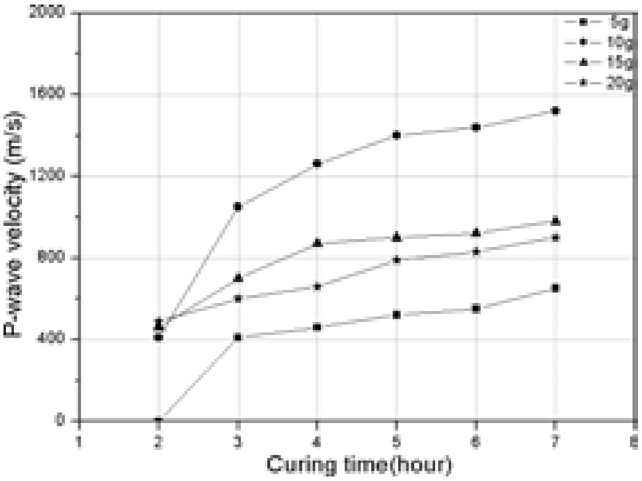
2. Selection of stemming materials for explosive demolition and proposed stemming methods

A variety of stemming materials such as white cement, powdered mortar, sand, and natural sand + crushed stone mixture have been used for explosive demolition, and lately the natural sand + crushed stone mixture material is gaining popularity, because it is easy to purchase and use. In this study, natural sand + crushed stone mixture (6 mm±2), non-shrinking grout mortar (REMIGROUT GP 400, Hanil cement co.) and white cement (REMIBOND TAG, Hanil cement co.) were selected to conduct field scaled single hole blast s for column specimen s based on the results from static and dynamic experiments[6)].

When it comes to stemming method by material, natural sand+crushed stone mixture were put into stemming plastic bag and cut into pieces of 5 (cm) compacted by stemming bar, and non-shrinking grout mortar and white cement were made into small lumps and inserted into holes compacted by stemming bar. Since it takes more than four hours from stemming to explosive demolition, non-shrinking grout mortar and white cement stemming materials need a mixing ratio providing rapid curing time after the four-hour period. Consequently, in this study, we measured elastic acoustic wave speed to know strength development time for non-shrinking grout mortar and white cement depending on the quantity of mixed accelerator, as in Fig. 1. The mixed stemming material was put into an acryl cylinder with a Φ45 (mm) diameter and a 50 (mm) length and elastic acoustic wave speed was measured until the speed was converged. The results show that non-shrinking grout mortar and white cement were found to be highest in elastic acoustic wave speed in four hours of mixing 10 (g) of accelerator. Specifically, mixing ratio for non-shrinking grout mortar should be water : non-shrinking grout mortar : accelerator = 81 : 14 : 5, and water : white cement : accelerator = 81 : 14 : 5 for white cement when 10 (g) of accelerator.



(a) Mixture of mortar and white cement

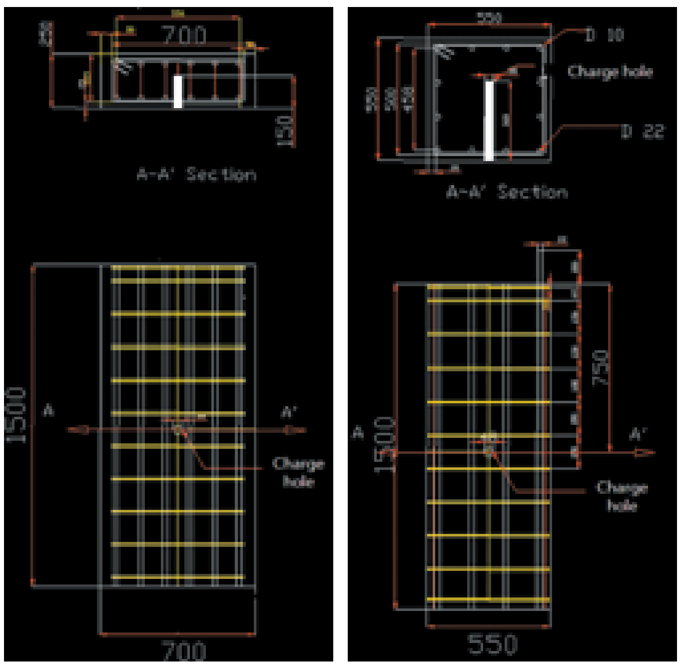


(b) Mixture of mortar and non-shrinking grout mortar

Fig. 1 Elastic wave speed-curing time profiles of white cement and non-shrinking grout mortar.

3. Preparation of column specimens and method of measuring dynamic data

Two types of column specimens were prepared. With its wider surface being the front, the rectangular type specimens of 250 × 700 × 1500 mm (width×length×height) was made of reinforced concrete blocks with a circular hole of a Φ45 (mm) diameter and a 150 (mm) length at the center. The 550 × 550 × 1500 (mm) square type column specimens were made of reinforced concrete blocks with a round hole of a Φ45 (mm) diameter and a 360 (mm) length at the center. The number of column specimens was 17 for each column. Figure 2 shows the section and cut view of columns which describe the steer bar arrangement and dimension. In order to protect the flying of fragments during blasting, the columns were lapped with thick Geotextile fabric (350 $g \cdot m^{-3}$) and galvanized wire net (#8). As in Fig. 3, the full



(a) Rectangular type (b) Square type

Fig. 2 Steel bar arrangement of columns.

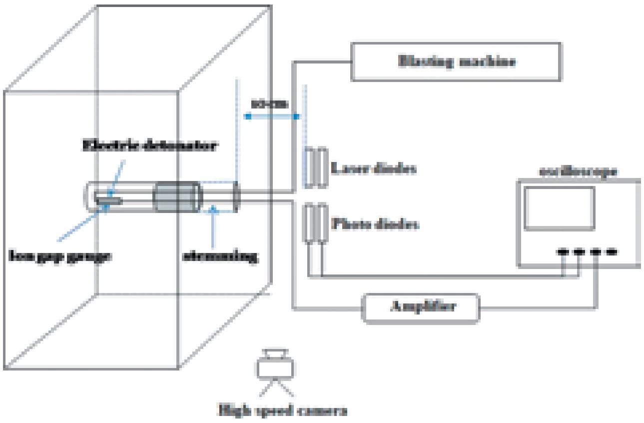


Fig. 3 Schematic description for full scaled−column blast and dynamic data measurements.

scaled−column blast was based on dynamic data using ion gap gauge to measure precise ignition time of the electric detonator and collapse speed of stemming materials with a laser speed indicator and thereby assess the effect of validity of stemming materials. Ion gauge allows for precise measurement of detonation times of the detonator and collapse time of stemming materials by providing trigger signals to a high−speed oscilloscope.

4. Trial blast tests for determining standard charge weights for full scaled–columns

We conducted a trial blast to calculate standard charge. To select the standard charge for the trial blast, equation (1)was used to obtain the mass of explosives by specimen.

$$L = C_a \cdot A \quad (1)$$

Where, L refers to mass of explosive (kg), A to area of the column (m^2), and C_a to coefficient of blast, for which 0.15 − 0.8 ($kg{\cdot}m^{-2}$) is preferable in the field. In this study, gelatin dynamite (MegaMITE 28 mm, Hanhwa co.) was used. The same protection method was applied to prevent flying of fragments during blasting and five sessions of trial blast for each specimen were conducted, respectively, varying charge weights of blast. The test condition for the trial blasts are summarized in Table 1. The fragmented area and damaged volume were examined with standard charge of 17.5 (g) and 90 (g) for rectangular type specimens and square type column specimens, respectively, as in Table 2.

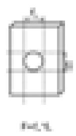
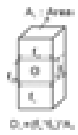
5. Results of full scaled–column blasts for stemming materials and discussion

Four blast tests for each stemming material were conducted as the same protection method and standard charge weight. Figs. 4 show examples of final fracture pattern in the front of the columns after blast test. Even different stemming materials, rectangular type columns show similar fracture patterns ; crushed area around the blast hole and preferential radial cracks. The square type columns showed severe crushed zone, bending of steel bars and separated fragments.

Table 1 Condition of the trial blasts for standard charge weight determination.

Type	No. of test	Hole length (mm)	Mass of explosive (g)
Rectangular type	1	150	12.5
	2		16.5
	3		16.5
	4		17.5
	5		17.5
Square type	1	360	50
	2		55
	3		83.3
	4		90
	5		90

Table 2 Results of the trial blasts.

Type	No. of test	Fractured area, F (m^2)	Damage volume, D_v (m^3)	Remarks
Rectangular type	1	0.23	−	
	2	0.25	−	
	3	0.24	−	
	4	0.33	−	
	5	0.31	−	
Square type	1	−	0.12	
	2	−	0.15	
	3	−	0.16	
	4	−	0.27	
	5	−	0.23	

5.1 Fragmented area and damaged volume

Figure 5 shows average damaged volume of square type column specimens and average fragmentation area of rectangular type specimens after the trial blast. Measurements of rectangular type specimens indicated that average fragmented area was highest in non−shrinking grout mortar, followed by natural sand+crushed stone mixture and white cement in order, while among square type column specimens, average damaged volume was highest in the natural sand + crushed stone mixture, followed by non−shrinking grout mortar and white cement in order.

5.3 Bending of reinforced beam

Results from the trial blast for rectangular type specimens showed no bending of reinforced beams, but there were radial cracks at front and back surface. We believe that this is because blasting pressure is depleted prior to any bending happening to the beams due to shorter stemming length. Figure 6 showed bending of reinforced beams of square type column specimens, which was highest in white cement, followed by non−shrinking grout mortar and natural sand + crushed stone mixture in order.

GM WC Bsand

(a) Rectangular type columns (gelatin dynamite : 17.5g)

WC GM Bsand

(b) Square type columns (gelatin dynamite : 90g)

Fig. 4 Fracture pattern in a sing hole blast columns (Front view).

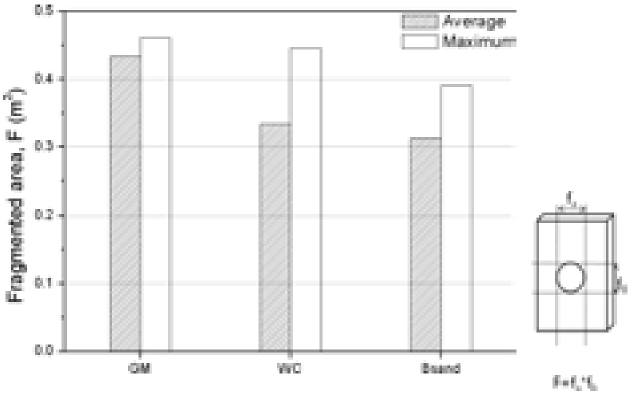
5.4 Collapse speed and flying speed of stemming materials

We need to measure the time taken for stemming materials, once collapsed by detonation pressure, to come out to hole entrance after explosion, that is, explosion time and the time required for stemming materials to be pushed out to hole entrance, in order to measure collapse speed of stemming materials. As shown in Fig. 2, explosion time can be measured with ion gauge, and the time for stemming materials to be pushed out to hole entrance in a dynamic signal measuring method using high-speed photo diode and laser beam. For flying speed of stemming materials, two pairs of high-speed photo diode and laser beam are employed to assess speeds at which stemming materials pass through. Figures 7 and 8 shows average collapse speed and flying speed by stemming material. Stemming material-specific average collapse speed of rectangular type specimens was lowest in non-shrinking grout mortar, while that of square type column specimens was lowest in white cement. When it comes to average flying speed, white cement was found lowest, likely resulting in shortest fly rock of all. The results revealed that white cement was highest in stemming resistance performance due to collapse speed and flying speed.

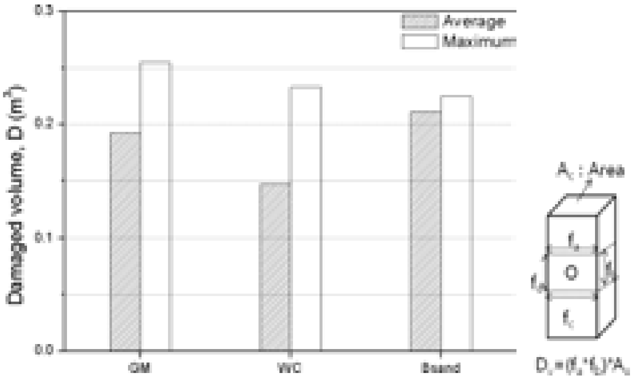
We took photos of hole entrance with a high-speed camera to observe fly behaviors of stemming materials. Figure 9 shows photos taken at a high speed during the blast of column specimens made of non-shrinking GM, white cement, and natural sand+crushed stone mixture. In non-shrinking grout mortar, flames due to the signal tube were seen before extrusion started in 0.8ms, and since then, almost linear concentrated fly rock patterns were identified. Whereas white cement flew stemming materials, scattering at a wide angle, natural sand+crushed stone mixture was scattered in a relatively wide range and flew materials rapidly. In addition, when the natural sand+crushed stone mixture was used, protective materials at the hole entrance were found to be expanded most rapidly.

5.5 What is the optimum stemming material in explosive demolition?

In consideration of rectangular type column blasts, non-



(a) Fragmented area of rectangular type column specimen



(b) Damaged volume of square type column specimen

Fig. 5 Fragmented area and damaged volume in a single hole column blasts.

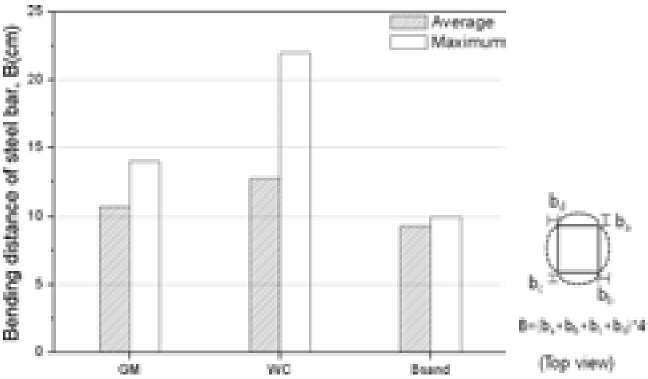


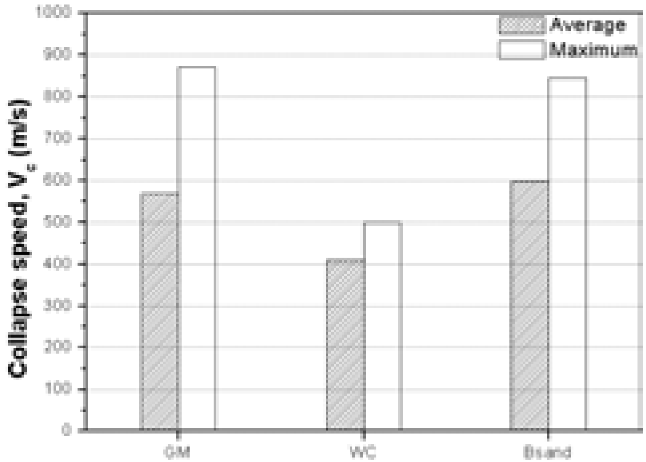
Fig. 6 Bending of reinforced beam by stemming material.

shrinking grout mortar was highest in blast efficiency and stemming resistance performance due to collapse speed. As a result, non−shrinking grout mortar is applicable in the rectangular type columns which have very short drill hole. In case of square type columns, three stemming materials should be applicable due to relatively long stemming length.

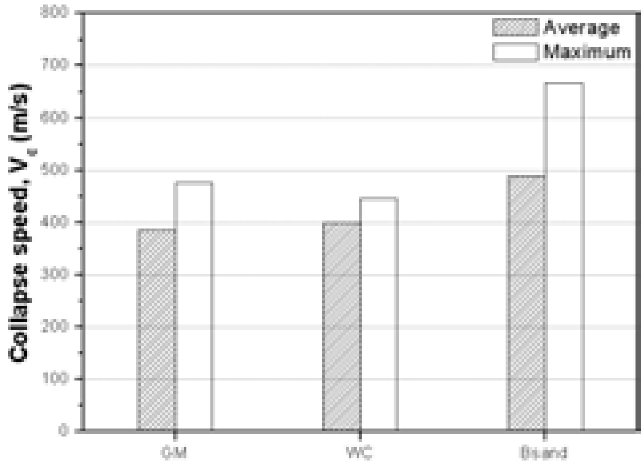
6. Conclusion

In this study, three stemming materials (natural sand + crushed stone mixture, non−shrinking grout mortar and white cement) were selected from various stemming materials applicable to explosive demolition in consideration of economy, constructivity, and site applicability. The findings from this study are summarized as follows :

1) From the findings of the standard charge trial blasts for columns with a full scaled single charge hole, we found



(a) Rectangular type column specimen



(b) Square type column specimen

Fig. 7 Collapse speed of stemming materials.

that standard charge of rectangular type specimens was 17.5 (g), and that of square type column specimen was 90 (g).

2) Among the rectangular type specimens, non−shrinking grout mortar showed highest average fragmented area, followed by natural sand+crushed stone mixture and white cement in order. In the case of square type column specimens, average damaged volume was highest in the natural sand+crushed stone mixture, followed by non−shrinking grout mortar and white cement in order.

3) Furthermore, there was no bending of reinforced beams among rectangular type specimens, while among square type column specimens, white cement showed highest degree of bending, followed by non−shrinking grout mortar and the natural sand+crushed stone mixture in order.

4) As far as average collapse speed of stemming materials was concerned, among rectangular type specimens, non−shrinking grout mortar was found to have lowest collapse speed, while among square type specimens, collapse speed of white cement was lowest. Average rock flying speed was lowest in white cement.

Acknowledgement

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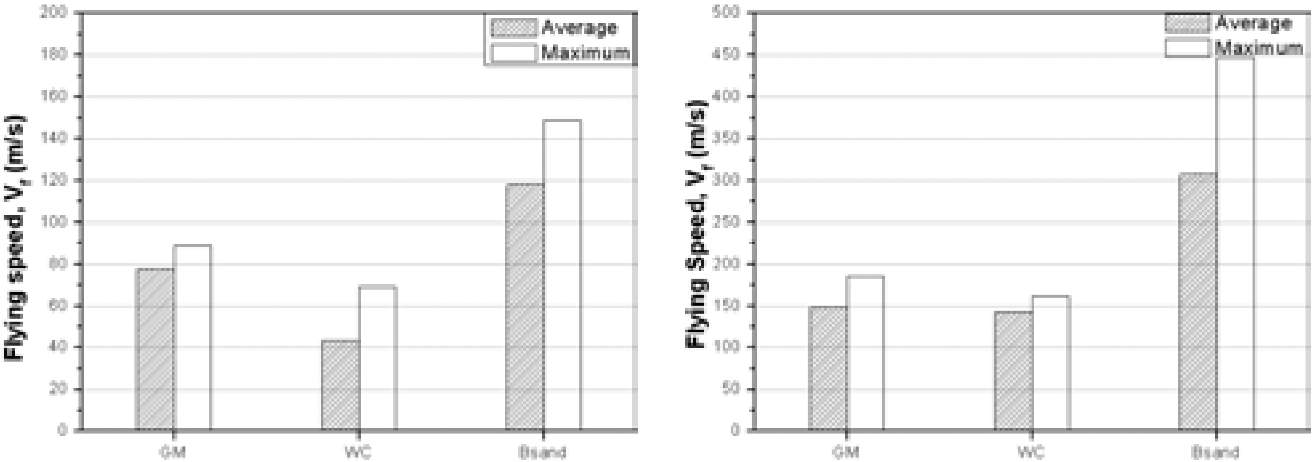

(a) Rectangular type column specimen (b) Square type column specimen

Fig. 8 Flying speed of stemming materials.

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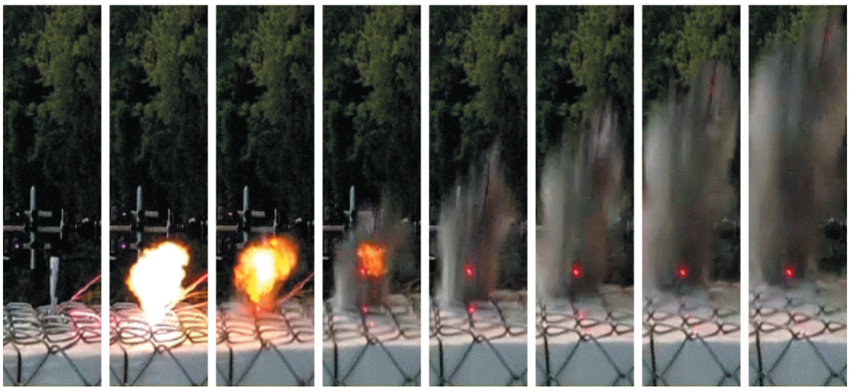
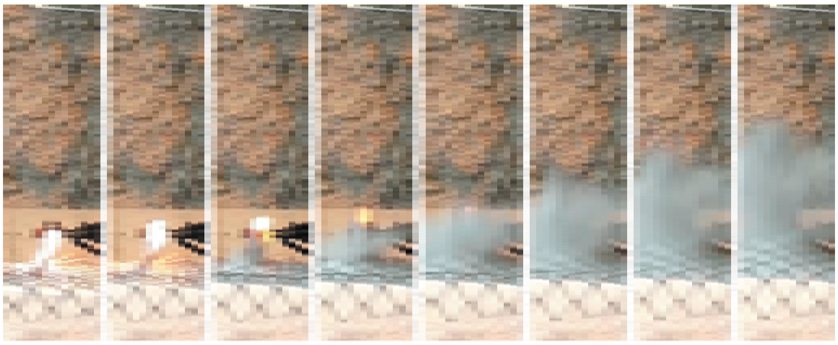


(a) Non-shrinking GM



(b) white cement

(c) Natural Sand+Crushed Stone

Fig. 9 High speed camera images of f lying s temming m aterials (1200 frames/sec).