



# THE ENERGY ABSORPTION OF MODIFIED FOAMED CONCRETE WITH RICE HUSK ASH SUBJECTED TO IMPACT LOADING

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## ABSTRACT

RiceHusk Ash (RHA) as sand replacement and filler of Foamed Concrete (FC) has contributed to increase the strength. FC with RHA has increased the slab resistant of impact loading. When RHA granulate filled the FC porous, it would delay the collapsing of cell porous due to the increasing strain of porous walls. The RHA granulate increased the elasticity of the porous walls of FC. Other than that, the walls porous would be more plastic when it was subjected to compressive stress that generated by impact loading. The impact test conducted an instrument drop-weight impact tower to generate various impact velocities of non-deformable impactor on slab of FC and FC with RHA. Results show that FC with RHA created the crater without fragments. Means while, FC clearly create radial crack and fragments within the crater field. However, both slab materials did not generate spalling nor scabbing upon impact and the influence of porosity produces only local damage due to the mechanism of brittle crushing effect of porous walls. This investigation observed that the energy absorption between FC and FC with RHA produced minor differences. However, the results verify that FC with RHA did not loss its ability to absorb energy upon impact.

**Keywords:** absorb, energy, impact loading, foamed, concrete RHA.

## INTRODUCTION

Conventional concrete generally is applied to construct in various structures, no exception used for defense and protective structure, such as barrier, shelter, road safety, retaining wall, coastal structures, nuclear containment, even bunker for military defenses purposes. As of that reason, that concrete not only bear normal loading such as weight, but also withstand the impact loading due to explosion or ballistic effect [1, 2]. from tornado debris, water flood, sea waves or tsunami, earthquakes, vehicle accident, and military ballistic system. Factually, although concrete can be designed to withstand the impact loading, however, it imperfectly absorbs kinetic energy. In some cases whether incidents and accident, secondarily people may be injured (even unto death) due to high velocity fragments of damage structure subjected to impact loading due to the impactor generates spalling, scabbing or rebounding [3, 4].

The growing interest in light weight concrete (LWC) is becoming apparent in recent years because of the special properties [5-7]. One of categorized as light weight concrete is foamed concrete (FC). FC has better energy absorbing capability and low cost in installation [8]. Basically, FC same material with traditional concrete, however FC not require the coarse aggregate and sometimes any light materials are added to increase the properties of FC such strength [9]. Nambiar and Ramamurthy [10] reported that strength of FC increased due to fly ash as finer filler added into FC admixture and replaced the sand in high ratio of strength-density.

This investigation, Rice Husk Ash (RHA) is used as filler and sand replacement in FC. The presence of RHA in concrete increase the strength [11], this applies

on the FC strength [12]. The characteristic of RHA as pozzolan material influence on improvement strength of concrete [13]. The RHA in this investigation was obtained from un-control burning below 700 °C precisely and pick up the expecting high pozzolanic activity index (produce amorphous crystal) [14], beside un-control combustion produced the RHA granuls as filler in FC. The presence of RHA granules, give the FC denser without losing its characteristics of porous. It was characterized by no occurrence the spalling or scabbing [15]. With this condition, FC+RHA would affect its energy absorption, compared with conventional FC.

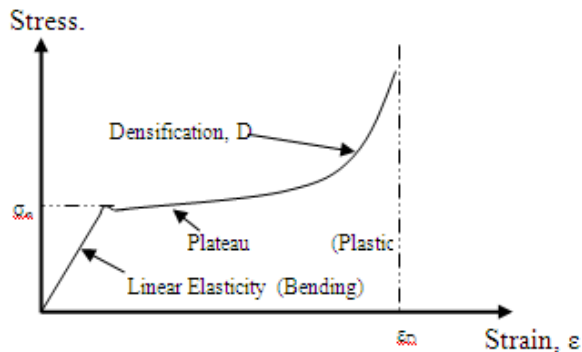
## IMPACT LOADING

### IMPACT LOADING ON FC

The characteristic FC is very prominent by air void, which more than 25% air entrapped in cementitious materials [16]. When impact loading applied to slab FC and initiate touch the slab surface, then the compressive stress wave that generated by impact loading propagate to the rear surface of the slab target causes the porous walls of FC stretched. The opposing walls of porous close to each other, which at the same time, strain in walls of porous increased, until the porous collapsing obtained. As the foam material that can absorb impact energy [17], in principle, FC as aerated concrete can be treated as foam materials [18]. However, when the walls of porous attained a state of brittle crushing, entrapped air was released and the point of surface loaded by impact gets denser and the target produces fragments as foam brittle materials. On this situation, eventually exhibits large increase in stress followed by a rapid reduction in strain,



i.e. its densification region, as it approaches its failure limits [18, 19].



**Figure-1.** Schematic compressive stress-strain curves for elastic-plastic cell walls of foam materials (Gibson and Ashby, 1997).

#### MECHANISM OF ENERGY ABSORPTION IN FC

A compressive wave that generated by impact loading when begins touch the surface target, will be initiated within the linear elastic region of the stress-strain curve of the concrete materials. However, if the target surface is not restrained, then this unrestrained surface condition reflects the compressive elastic wave as tension, in the longitudinal direction further propagating back from the distal surface [3][19]. If the slab target is brittle and low in tension, then the reflection tensile wave produces fractures causing parts of the materials around the surface target to be separated and break away or spalling. Also in rear surface will produce the scabbing due to transverse wave direction [20].

The shock loading produced by impact influence the energy absorption mechanism of materials [19]. In the case of elastic stress wave, normal stress wave similarly produced were found to be smaller than the yield stress of the target material. The plastic stress wave is generated when the stress wave goes beyond the yield stress of the material [19]. Both stress waves affect the energy absorption of the materials, higher stresses are gained along the surface of the target material. Furthermore, the stress wave generated strong compression plastic wave and upon reaching its limits of elastic material causes local plastic collapse to occur. The plastic collapse in foam brittle material produces fragments whilst the absorption of energy takes place [18]. The process of absorption energy is related to the force released by the impactor upon hitting the surface of the target. Simply by using the law of conservation of energy, energy absorption equals the reaction of target against forces of impactor generated from its mass and acceleration as work done and the penetration depth is the realization of work done.

$$E_a = m \cdot g \cdot X \quad (1)$$

Where  $E_a$  is energy absorption, the force of impactor reflect in the current experimental work from the

impactor mass  $m$  will be equivalent to the acceleration of gravity  $g$  at  $9.81 \text{ m/s}^2$  and  $X$  is the penetration depth.

#### EXPERIMENTAL

##### SLAB TARGET FABRICATION

This experimental investigation conducted the Pre-foaming method to produce target density  $1800 \text{ Kg/m}^3$  of foamed concrete with RHA. Ratio of cement-water was 0.60 and ratio of cement-sand was 0.25 [12]. The density  $50 \text{ Kg/m}^3$  of foam was obtained from aqueous surfactant solution diluted by water 1:5 [21, 22]. Afterwards the stable foam blended gently into the base mix until reach target density. Base on chemical composition RHA is similar with fly ash [23]. So that the investigation of RHA was treated as originally fly ash. The RHA obtained from rice manufacturer and uncontrolled burning under  $700^\circ\text{C}$  during  $\pm 6$  hours. The composition of cement-sand-RHA was 1:3:1 with 1.25 ratio of RHA-water. The RHA was mixed into concrete admixture before foam blended into admixture. Target specimens produced into 600mm length, 600mm width, and 160mm thickness of slab. Area surface and thickness were considering to previous investigation to prevent scabbing and perforation for concrete [4, 24-26]. All specimens cured for 28 days in temperature  $23 \pm 2^\circ\text{C}$ .

##### IMPACT TEST

Falling-weight impact method was conducted in this investigation, which used an instrument of falling-weight impact tower. The rigid non-deformable impactor on concrete and ceramic was released with various elevations of 5m, 4m and 3m or various velocities at 10 m/s, 8.9 m/s and 7.7m/s respectively. The impactor was made of urethane and polymer composite with 5.9 kg by weight, 218mm of diameter and  $1094 \text{ kg/m}^3$  of density.

#### DISCUSSION AND ANALYSIS

##### STRENGTH AND PENETRATION DEPTH OF FC WITH RHA

FC with RHA as substitute to fine aggregate was denser but light in weight owing to the carbon ash (granulate) fill bubble space in FC. Besides that, the continuous hydration process from pozzolanic (characteristic of RHA) reaction throughout the curing stage made the FC with RHA to increase its strength [15]. In case of a slab FC target subjected to impact loading, porous walls of FC produced bigger strain as a response to the compressive wave. Afterwards, the increasing strain formed the plateau-region in stress-strain curve. It was larger than the compressive plastic stress. This condition went on until plastic stress increased and the strain decreased rapidly.

When the porous was filled by RHA granulate, collapse would be delayed due to the altered of strain of porous walls. Apart from that, the presence of granulate also increased the elasticity of the porous walls and there would be more plastic and less of fragments [15].



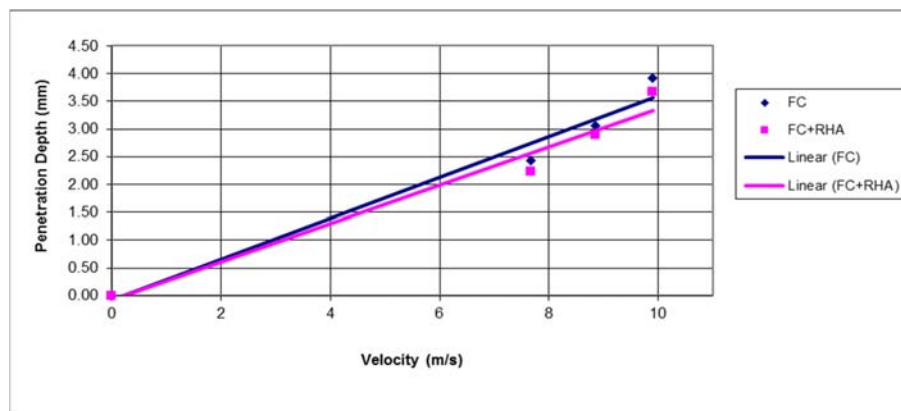
However, presence of RHA also reduced number of porosity, which the FC would denser than FC and increase the strength [27]. Table-1 shows that FC with RHA stronger than FC. The strength of those concretes influence on impact effect [28].

**Table-1.** Compressive and tensile strength of FC and FC with RHA.

Material	Density (Kg/m <sup>3</sup> )	Compressive strength (N/mm <sup>2</sup> )	Tensile strength (N/mm <sup>2</sup> )
FC	1800	6.190	2.82
FC +RHA	1800	10.490	4.29

#### PENETRATION DEPTH ON FC WITH RHA

The result from Figure-2 shows the penetration depth of FC was deeper than FC with RHA. This corresponds to their strength[28], which FC was weaker than FC with RHA.



**Figure-2.** Penetration depth FC and FC with RHA.



**Figure-3.** (a) FC + RHA slab surface and (b) FC slab surface after stroke by impactor with 9.9 m/s impact velocity.

The compressive strength of FC with RHA achieved 69.6% greater strength than FC. Figure-3a shows FC under 9.9 m/s impact loading created the radial crack and fragments, means while, Figure-3b obviously fragments were not found in FC with RHA was subjected to impact loading.

The fragments indicated that brittle crushing mechanism on foam material in field crater of impact has been occurred [18]. This results even was supported by not found the scabbing nor spalling.

#### ENERGY ABSORPTION

Presence the RHA contributed to increase the strain of FC porosity and delayed the porosity collapsing, even the RHA made the FC was denser. This affected to

materials energy absorption. Table 2 presents comparison between energy absorption of FC and FC with RHA. Equation (1) is conducted to calculate the energy absorption both of materials. Penetration depth was available from experimental result. From Table 2, the energy absorption both materials was not significant, although FC with RHA has been increased its strength.

Penetration depth of FC in all experimental impact velocity was deeper than FC with RHA. It was companied by an increasing diameter of crater. It is obviously that the response of FC with RHA gives compressive stress in walls porous higher than FC to reaction the compressive force due to impact loading. From the energy absorption results, this is evident that the



presence of the RHA in the FC does not change the ability to absorb energy.

**Table-2.** Energy absorption of FC and FC with RHA.

Slab target material	Impact velocity	Compressive strength	Penetration depth	Energy absorption
	(m/s)	(N/mm <sup>2</sup> )	(mm)	(Nm)
FC	7.7	6.19	2.4	0.1419
FC	8.9	6.19	3.1	0.1783
FC	9.9	6.19	3.9	0.2278
FC + RHA	7.7	10.49	2.2	0.1300
FC + RHA	8.9	10.49	2.9	0.1681
FC + RHA	9.9	10.49	3.7	0.2134

Factually, the energy that produced by impact loading is not absorbed entirely by slab. The energy can also be converted into other variables such as thermal, noise or another factor that are not considered in the simplified calculation but contribute to energy absorption.

In this investigation, residual energy visually can be impressed by behavior of impactor after stroke the target. Table-3 shows the energy that created by impactor

velocities 7.7 m/s and 8.9 m/s on FC almost can be absorbed as well. Meanwhile, impact loading by 9.9 m/s cause the impactor rolling on. FC with RHA demonstrates more residual kinetic energy of impactor; those are impressed by bouncing of impactor after hit the target. This is evident that the compressive strength affects the material ability to absorb energy.

**Table-3.** Behaviour of impactor after stroke on foamed concrete and its modifications.

Slab target	Impactor velocity (m/s)	Penetration depth (mm)	Local effect	Impactor condition after hit the target
FC	7.7	2.4	Cratering	Almost stuck
FC	8.9	3.1	Cratering	Almost stuck
FC	9.9	3.9	Cratering	Rolling
FC+RHA	7.7	2.2	Cratering	Bounce
FC+RHA	8.9	2.9	Cratering	Bounce
FC+RHA	9.9	3.7	Cratering	Bounce

## CONCLUSIONS

Presence RHA as pozzolanic materials gives contribution to increase the strength of FC. Besides, granulate form of RHA fill the FC matrix and increase the strain of FC porosity and delayed the porosity collapsing when against compressive stress that generated by impact loading.

However, the FC with RHA is not loss its ability to absorb energy. The differences between FC and FC with RHA are the local damage results, which the FC with RHA less of crack and fragments in crater field, although both of slab materials did not produce spalling nor scabbing when impact loading applied.

## ACKNOWLEDGEMENT

The author would like to thank to the Universiti Tun Hussein Onn Malaysia (UTHM), Johor Malaysia and acknowledgment the research and staffing resources provided by the Faculty of Civil and Environmental Engineering and Research, Innovation, Commercialization, and Consultancy Management Office of Universiti Tun Hussein Onn Malaysia (ORICC-UTHM), Malaysia.

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