Key Engineering Materials Vols. 594-595 (2014) pp 24-28

doi:10.4028/www.scientific.net/KEM.594-595.24

Investigation on Impact Resistance Foamed Concrete Reinforced by Polypropylene Fibre

Ahmad Mujahid Ahmad Zaidi[1,2,a], Josef Hadipramana[3,b], Abdul Aziz Abdul Samad[1,c] and Noridah Mohamad[1]

[1]International College of Automotive, Kompleks Automotif DRB-HICOM Pekan, Karung Berkunci No. 8, 26607 Pekan, Pahang, Malaysia

[2]Departement of Mechanical Engineering, Faculty of Engineering Universiti Pertahanan Nasional Malaysia, Kem Sungai Besi 5700, Kuala Lumpur-Malaysia

[3]Faculty of Civil and Environmental Engineering Universiti Tun Hussein Onn Malaysia, Parit Raja-Batu Pahat 86400, Johor-Malaysia

[a]mujahid80s@yahoo.com, [b]hdjosef@yahoo.com, [c]azizs@uthm.edu.my,

Keywords: foamed concrete, polypropylene, fibre, impact.

Abstract. Foamed Concrete (FC) needs high strength to prevent dynamic loading, thus it is important to enhance the ductility. Usage the Polypropylene Fibre (PF) examined its contribution in strength of FC on impact resistance. Microstructures were observed that air voids in matrix of FC produce micro-porous that reduce interfacial bonding into matrix and generate micro-crack that may propagation crack growth. Presence of PF in admixture results fibrillation and reduces micro-cracks. Tensile test was investigated that PF delays crack growth in matrix. In this investigation impact test were conducted using an instrumented drop-weight impact tower. When impactor hits the target surface in free surface condition causes compressive plastic wave transform to be tensile wave. It was affected by tensile strength therefore local effect has not found spalling in crater field. In addition influence of porous in matrix FC has ability to absorb the energy and it was not found distal crack around surface area. Penetration depth results showed FC with PF subjected to impact loading was lower than without FC. Presence of PF increases FC strength and local effect results there was not impression of fragments around distal surface due to brittle crushing.

1. Introduction

Historically concrete has been widely used to construct various structures, no exception to structure shield such as retaining wall, shelter, barrier, nuclear reactor containment, offshore structures etc. The dynamic impact loading is consequently relates to the penetrability of concrete in relation to projectile and resistance concrete against ballistic and explosion. Although conventional concrete can be design to prevent local impact effect [1], however as a structural shield the concrete has problems, in some cases whether incidents and accident, secondarily people may be injured due to high velocity fragments of damage structure (spalling, scabbing or rebounding) [2], further is called ballistic effect. Ballistic effect has been acted due to natural forces such as tornado-borne debris, earthquake-wave, volcanoes rocks fall, tsunami, water flood, they generate impact loading or effect of blast loading. Also in an accidental such as vehicle collision, aircraft crashes, in addition projectile (e.g. bullet, rocket) that used in military application system. It is obviously conventional concrete cannot completely absorb energy. In addition installation of concrete structure very costly. Therefore the requirements of lightweight concrete that can absorb energy are indispensable. Foamed concrete (denoted as FC) be sides lightweight and low cost, it exhibit excellent characteristics including high strength, energy saving, waste utilizing, heat preservation and noise insulation. [3].

Although FC can absorb impact energy due to porosity [4], however the air void influence the strength [5-7]. Characterization porous such as volume, size, spacing and pore size distribution is primary factor to influence material properties of FC mainly on density and strength. FC with narrower cell-size distribution normally has high strength [5]. However The bubbles into FC matrix produce micro porous [8]. It may reduce interfacial bonding in the matrix and cause micro-crack, afterwards propagation crack growth. Structure shield needs high strength to prevent dynamic loading, thus it is important to enhance the ductility [9]. The presence Polypropylene Fibre (denoted as PF) that drawn into admixture resulted fibrillation and interfacial bonding between PF and matrix eventually reduce micro-cracks [10-12]. Penetration depth of FC with PF subjected to impact loading is lower than without FC. Impact resistance of FC has influenced by porosities and strength of FC has altered by presence of PF.

2. Impact Resistance on FC

Local effect neither occurs spalling nor scabbing when impactor hits target FC due to impact loading. In case where FC contains a lot of the air cavities so may percolate much energy impact. Effect stress wave propagation relates on energy absorption and densification [4]. FC containing many air porous which compressed by stress rapidly or impact is similarly as honeycombs cells analysis [13]. When impact loading applied to slab target and impactor start to touch the surface, then compressive elastic wave initiate the linear elastic region in stress-strain curve.

In this investigation the surface target was free and the constraints were conducted on both sides of the bottom of the slab. The free surface condition transmits the reflection of compressive elastic wave in longitudinal direction to be a tensile and propagates to back from the distal surface [2, 14]. If the slab target is brittle and low tension then the reflection tensile wave will produce the fracture and a part of materials in layer around the surface target will be separated and fly away. This failure condition is called spalling.

Along with that, when compressive stress wave reflected propagate through to rear surface of target or transverse direction then the walls of porous are stretching, furthermore opposing walls of porous close each other until almost collapse. This condition causes altering strain walls of porous strain and create plateau region in stress-strain curve. The collapse of walls of porous is called brittle crushing. Afterwards the strain decrease and target surface compresses the solid itself. Increasing rapidly of the stress will be reach final region. When the relative density of FC increase then the Young's modulus will increase so will increase plateau stress and reduce the strain. It is that called of densification region [13].

3. Experimental

3.1 Material Properties

In this investigation pre-foaming method were applied to develop target specimens. Cement, sand and water get mixed to prepare base mixture of concrete whilst the stable foamed produced separately. Then thoroughly blending foam into base mix until reach target density. Furthermore Chopped PF with 22 μm of diameter and 18 mm length was mixed into FC admixture with 0.33 dosages of PF. The PF has tensile property 300 N/mm^2 and density is 0.89E-4 Kg/cm^3. The admixture ratio was made by 0.60 of water-cement ratio and 0.25 of cement-sand ratio. In the mean time, density of foam was 50 Kg/m^3 or ratio 1:5 water-foam agent [15]. The blending pursued to get the specimens with 1800 Kg/m^3 of target densities of foamed concrete. Specimens produce into two mixtures. First, they were used PF into mixture and the other mixture were without PF.

The all specimens were molded and maintained at temperature 23±2°C for 24 hours. After casting, the specimens were removed from the mould and cured for 28 days with the same temperature. The specimens were made to carry out the strength [16].

By the same way, the slab target produced with 600mm of length, 600mm of width and 160mm of thickness. Determination area surface and thickness were considering previous investigations to specify thickness concrete to avoid failure in scabbing and perforation on material concrete subjected to impact loading [1, 17-20].

3.2. Impact Test

Impact test were conducted using an instrumented falling-weight impact tower. The rigid non-deformable impactor was released with various elevations 5m, 4m and 3m or various velocities 10 m/s, 8.9 m/s and 7.7m/s respectively. Actually the impactor is a ball shape and non-deformable impact on concrete and ceramic. It is represent the model of a non-deformable projectile with blunt nose. In present experiment the impactor is made of urethane and polymer composite with 6 kg by weight, 218mm of diameter and 1094 kg/m^3 of density.

4. Result and Analysis

4.1. Compressive and Tensile Strength

Previous investigations conclude that strength of concrete increase when the PF mix into concrete admixture as reinforcement [21-24]. Table 1 shows compressive strength FC with PF is greater than FC without PF. It can be explained that PF in FC admixture have been occurred fibrillation with matrix concrete. Bonding mechanism system between PF and matrix is reach. It is agree with any investigations on concrete with PF [25, 26].

Table 1. Compressive and Tensile Strength FC and FC+PF.

Material	Density Kg/m^3	Tensile Strength N/mm^2	Compressive Strength N/mm^2
FC	1800	4.270	6.190
FC +PF	1800	4.700	14.786

Determination of tensile strength of FC is more sensitive to the condition of the test than compressive strength [27]. Presence of PF in matrix FC retards crack growth in matrix and FC more require stress before critical crack propagation occurs[28]. Table1 shows FC with PF obviously higher than FC without PF. The presence PF about of porosity in foamed concrete instead create critical crack occur faster.

4.2. Penetration Depth

Since impactor hit the target surface, then the material respond to rapid dynamic loading or impact loading, with its way. The response of FC is giving compressive stress in walls porous to reaction the compressive force due to impact loading. This reaction produces bigger strain in material. Enhancement of strain results the plateau region in stress-strain curve larger than the compressive plastic stress. This condition goes on until plastic stress increase and decreasing of strain rapidly, by means walls porous collapse and air which entrapped in porous release out thus the material denser or densification [4]. All this process means the material is absorbing the energy impact and it relates to plastic energy absorbed by the graded cellular structures [29], that the plastic energy not only reduces the contact force but also dictates the amount of energy consumed in negative work done by the materials.

Figure 1 depicts that penetration depth of impactor relates on impact velocity, and the trend shows penetration depth FC without PF is higher than FC with PF. It is clear that FC with PF denser and more strength than FC without PF. The presence of PF reduce amount of porosity. It is agree with Jones and Zheng [30], that decrease in the amount of porosity in FC and reduce the penetration depth. It is attributed to the porosity, whether volume of bubbles phase, local strength the bubbles walls and/or the size of bubbles. In this investigation compressive plastic wave transform to be tensile owing to the constraints were free condition at surfaces when the impactor stroke the surface. Figure 2 shows that local effects do not produce spalling or any cracks on around distal surface target. It is because influence of porosity [4, 30]. However presence of PF in FC, the target specimens to be more strength and there is no impression of fragments due to brittle crushing (2-a) [30].

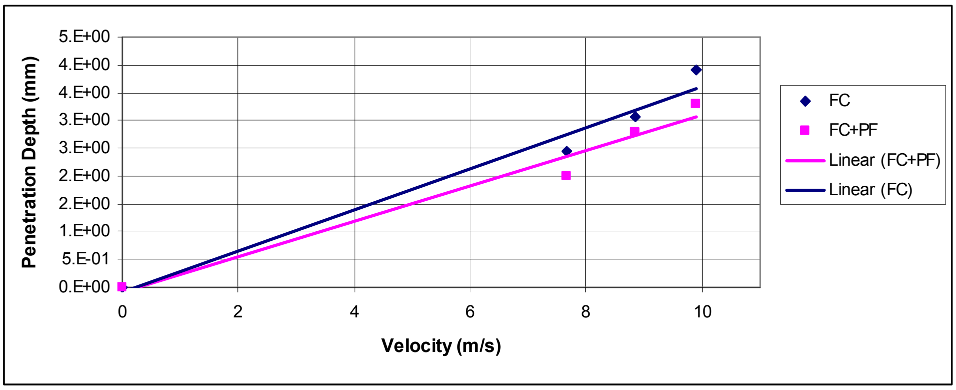

Fig. 1 Penetration depth on FC with and without PF

(a) (b)

Fig. 2 Local effects due to impact loading with 10 m/s of impact velocity (a) FC without PF and (b) FC with PF

5. Conclusion

Mechanical anchoring occurs when the PF and concrete matrix interlocking. Bonding mechanism which interfacial adhesion that relation between FB and matrix to bond tightly at the actual interface along cement hydration process. The presence of PF into matrix causes bridging force crossing the crack occur and reduces propagation crack growth and increase both of compressive strength and splitting tensile strength.

FC actually has been enough to restrain impact loading and absorb energy impact, however impact resistance of FC has influenced by porosity and strength of FC has altered by presence of PF.

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