Construction and Building Materials 122 (2016) 72–80

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Dynamic response of expanded polystyrene concrete during low speed impact

Yiping Liu, Dongpeng Ma, Zhenyu Jiang *, Fan Xiao, Xinxiong Huang, Zejia Liu, Liqun Tang

School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510640, China

HIGHLIGHTS

- Impact response of EPS concrete is studied on a drop hammer testing machine.
- Deformation of EPS concrete during the impact is monitored using high speed camera.
- The dynamic response of EPS concrete is found to be a four-stage procedure.
- The fracture of EPS concrete develops progressively during the impact.
- Energy dissipation of EPS concrete depends on its fracture mode.

ARTICLE INFO

Article history:
Received 25 January 2016
Received in revised form 26 May 2016
Accepted 14 June 2016

Keywords:
Expanded polystyrene concrete
Dynamic response
Impact test
Drop hammer
High speed camera
Energy dissipation

ABSTRACT

The impact response of lightweight concrete filled with expanded polystyrene beads (EPS concrete) has been studied experimentally using a drop hammer system equipped with a high speed photography system. According to the impact force-time curves and the images of specimen surface obtained during the tests, the impact response of EPS concrete can be summarized as a four-stage procedure. The damage of EPS concrete is found to be a progressive process, which initiates from the upper part and develops downwards, leading to fluctuation of impact force. Based on the experiments, the energy dissipation capability of EPS concrete is evaluated, which demonstrates a dependence on the fracture mode of EPS concrete at the impact velocities in a range of 2–4 m/s. The energy dissipation capacity of EPS concrete is found insensitive to the EPS volume fraction, when it is in a high range from 70.2 to 80.3 vol%. Up to 18.6% increase in energy dissipation is observed in the concrete with 80.3 vol% EPS under impact at 4 m/s.

1. Introduction

Since Cook reported his work on concrete using expanded polystyrene (EPS) beads as aggregate in 1973 [1], EPS-filled concrete (EPS concrete) has attracted increasing interest and found a wide variety of applications in civil engineering, including building construction [2], highway foundations [3] and marine platforms [4]. Closed-cell EPS beads have some distinguished advantages, e.g. ultra-low density, thermal insulation, hydrophobic nature, low cost and good commercial availability, which make them a type of promising aggregate for lightweight concrete. In the past decades, intensive research effort has been devoted to the characterization of the mechanical properties of EPS concrete, in particular compressive strength [5–18], splitting tensile strength [8–10,14,15,17,18] and flexural strength [12,15,17,18], as well as the controlling factors (e.g. curing condition [9,12], EPS content [8,9,16–18], bead size [7,10,11,13,14,17], and additives [7–9,12,14,15]). Based on the experimental study, micromechanical models [11,13,19] and phenomenological models [10,16–18,20] have been developed to explain how the EPS content and bead size influence the mechanical performance of EPS concrete.

The use of EPS concrete can be extended to military or civilian protective structures [5,21], due to not only its energy absorption feature, but also good resistance to corrosion, water attack and severe variation of service temperature [22,23]. However, the research on mechanical response of EPS concrete subjected to impact is still in its early stage compared with the investigation on its quasi-static mechanical properties. Few works concerning the dynamic response of EPS concrete has been reported heretofore. Bischoff et al. performed a pioneering study on the energy absorbing capacity of EPS concrete and its reducing effect on contact loads during hard impact [21]. Wu et al. performed a series of tests on split Hopkins pressure bar [24,25], which revealed the strain rate

* Corresponding author.
E-mail address: zhenyujiang@scut.edu.cn (Z. Jiang).

http://dx.doi.org/10.1016/j.conbuildmat.2016.06.059
0950-0618/

sensitivity of the dynamic compressive and splitting tensile strength of EPS concrete.

The reported dynamic properties of EPS concrete, e.g. relatively low crushing strength and large deformation capacity, combined with its good environment tolerance, make it a competitive candidate for the engineered materials arrestor system (EMAS), which is one of the prominent applications of lightweight concrete. The EMAS is a bed built at the end of an airport runway [26,27]. The overrunning aircraft can be efficiently decelerated by dissipating the energy through the crashing of the EMAS material. In this paper, a preliminary experimental study on the dynamic response of EPS concrete has been carried out at low impact velocity using a drop hammer testing machine. The deformation and damage on the surface of EPS concrete during the impact is characterized using a high speed photography system synchronized with the drop hammer testing machine. Based on the observation, failure mechanisms and energy dissipating capability of EPS concrete are analyzed.

2. Experimental program

Table 1 lists the ingredients of the three EPS concrete systems prepared in this work. The 325-grade Portland cement (PC32.5R, supplied by Guangzhou Shijing Cement Co., compressive strength is about 32.5 MPa) was mixed with the commer-

Table 1
Ingredients of the three EPS concrete systems.

Portland cement (g)	Expanded polystyrene (g)	Water (g)	EPS volume fraction (vol%)
607.1	7.2	242.9	70.2
571.4	7.6	228.6	72.3
400.0	7.8	160.0	80.3

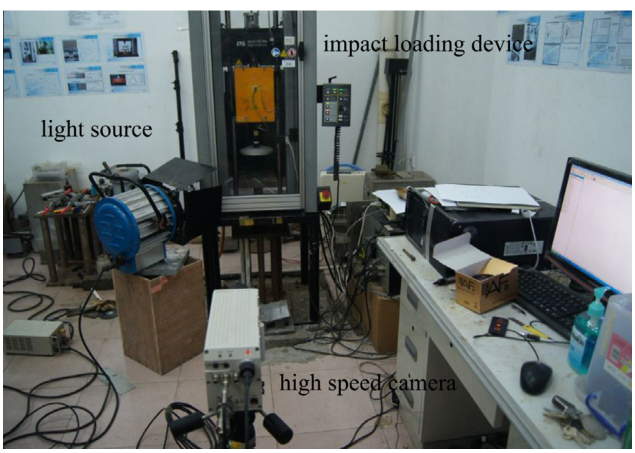

Fig. 1. Instron Dynatup 9250HV drop hammer testing machine and a synchronized high speed photography system.

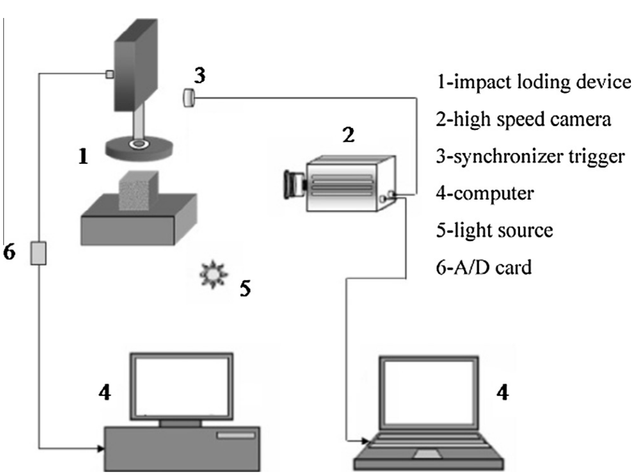

Fig. 2. Illustration of synchronization between the drop hammer testing system and the high-speed photography system.

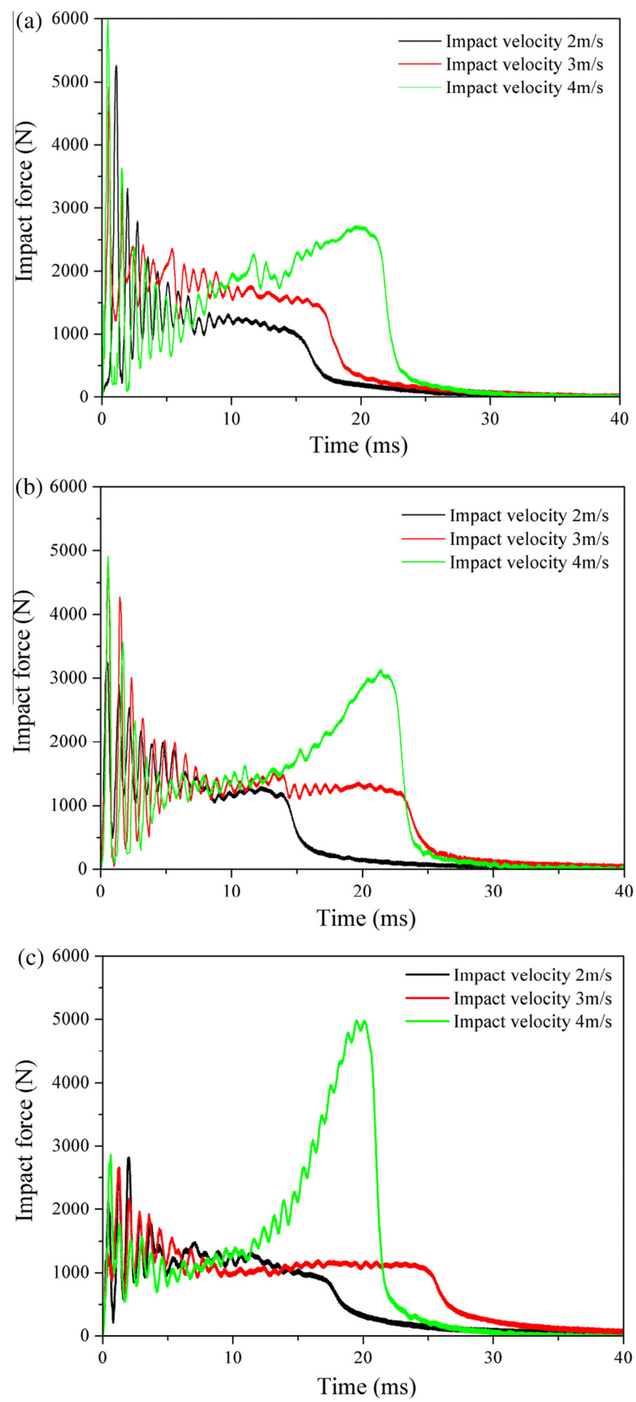

Fig. 3. Impact force-time curves of EPS concrete containing (a) 70.2 vol% EPS, (b) 72.3 vol% EPS, and (c) 80.3 vol% EPS during the impact at 2 m/s, 3 m/s, and 4 m/s.