# Study the Size Effect of EPS Concrete on Its Compressive Strength

Qiang Li*, Hairong Dong, Jianmin Su, Xiaoliang Zhang, Hui Guo, Debai Zhao and Quanpeng Liu
*School of Vehicle Engineer, Weifang University of Science and Technology, No.1299 Jinguangjie, Shouguang, Shandong, P.R.China, 262700*

Keywords: EPS concrete, ratio of EPS bead radius to specimen size (r/a), compressive strength; volume fraction

Abstract: The effect of the ratio of EPS bead radius to the specimen size (r/a) on the compressive strength is investigated by theoretical deduction. The results show that r/a, as well as volume fraction, plays an important role in affecting the compressive strength. The volume fraction of EPS beads determines the minimum compressive strength of EPS concrete specimen, the higher volume fraction, the lower the minimum compressive strength. The maximum compressive strength is relied on r/a. When r/a is smaller than 0.05, the effect of r/a can be neglected. As the EPS volume fraction increases, the maximum and the minimum compressive strength will be affected by changing r/a. Therefore, reducing the density and enhancing the compressive strength of EPS concrete can be accomplished by adjusting r/a value to a certain value under a certain volume fraction.

## 1 INTRODUCTION

Expanded polystyrene (EPS) concrete with low density, high thermal insulation properties arouses great interest from industries and research institutes for its wide applications, such as sub-base material for pavement and railway track bed, construction material for floating marine structures, sea beds and sea fences, ceiling and thermal insulation wall et al (Babu and Babu, 2003; Babu et al., 2006).

Although there are lots of advantages and wide applications of EPS concrete, the low mechanical properties of EPS concrete is one of its distinct weaknesses. In the past decade, there were lots of researching works were related to mechanical properties of EPS concrete (Babu and Babu, 2003; Chen and Liu, 2013; Miled et al., 2004; Ling and Teo, 2011; Bouvard et al., 2007).

Mild et al (Miled et al., 2004; Miled et al., 2007) investigated the size effect of EPS beads on the compressive strength and the failure. In their model (Miled, 2004), the damage initiation and distribution in the specimen were calculated. However the model was a 2d model that couldn’t reflect the 3D situation. Miled (Miled et al., 2007) et al used the experimental method and numerical method to investigate the influences of size of EPS beads on its compressive strength and found the finer EPS beads, the higher compressive strength.

In 2005 Laukaitis et al (Laukaitis et al., 2005) studied the effect of polystyrene size on the compressive strength of EPS concrete. Their experiment showed the fine polystyrene had the highest compressive strength and the crumbled polystyrene had the lowest compressive strength.

There are also some research works about EPS structure (Bouvard et al., 2007), fabrication and physical properties, and numerical simulation (Fu and Dekelbab, 2003; Liu et al., 2012). However the influence of ratio of EPS bead radius to specimen size on the compressive has not attracted enough attention. In this article, the relationship between ratio of EPS bead radius to specimen size (r/a) and compressive strength was built.

## 2 PHYSICAL MODEL

According to Song et al (Song et al., 2008) researching work, the upper limitation of volume fraction for randomly packing of equal radius spheres is 0.634. Therefore, the upper limitation for EPS volume fraction is set less than 0.6. The specimen of EPS concrete is adopted as cubic shape, and its size is $a \times a \times a$, the radius of EPS bead size is $r$, The volume fraction of EPS beads is $\varepsilon$, r/a is the ratio of EPS bead to sample size.

Compared with solid concrete, the compressive strength of EPS beads is very tiny. Therefore, the



Li, Q., Dong, H., Su, J., Zhang, X., Guo, H., Zhao, D. and Liu, Q.
Study the Size Effect of EPS Concrete on Its Compressive Strength.
DOI: 10.5220/0008186801390142
In *The Second International Conference on Materials Chemistry and Environmental Protection (MEEP 2018)*, pages 139-142
ISBN: 978-989-758-360-5

compressive strength of EPS beads is neglected in this paper, and the compressive strength of EPS can be regarded as the strength of the solid concrete. Because the compressive strength is defined as: $f = \frac{F}{S}$, where F is loading force, and S the cross section area, so the compressive strength of EPS concrete is depended on the solid concrete area excluded the EPS beads occupied area. Here, we divided the EPS distribution in concrete matrix into three situations: loose packing, high density packing and others mode packing of EPS beads.

## 2.1 Loose Packing Model of EPS Bead

In this paper loose packing model means that in any cross section of specimen, there is no overlap between two neighbouring layers of EPS beads, and the compressive strength can be deduced as:

$$f_c = f_0\left(1-\left(\frac{9\pi\varepsilon^2}{16}\right)^{\frac{1}{3}}\right) \tag{1}$$

where $f_0$ is the compressive strength of completely solid concrete, here $f_0$ is set as 40 MPa. $f_c$ is the compressive strength of EPS concrete, ε is EPS volume fraction. That is to say, the compressive strength is only depended on ε.

## 2.2 High Density Packing of EPS Bead

When there is overlap between any two neighbouring layers of EPS beads, the compressive strength of EPS concrete is expressed as Equation 2.

$$f_c = f_0\left(1-\frac{\pi}{2\sqrt{3}}\left(1-\frac{2r}{a}\right)^2\right) \tag{2}$$

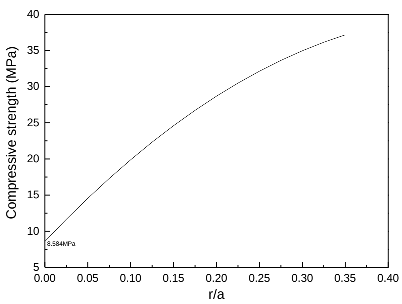


Figure 1: Relationship between r/a and compressive strength.

Figure 1 shows that the minimum compressive strength is 8.58MPa, and as r/a increases, the compressive strength increases too.

## 2.3 Other Mode Packing EPS Beads

To investigate impact of r/a on compressive strength, r/a can be divided into following situations.

1) When there is only one EPS bead in the concrete specimen and the radius of EPS bead increases from very tiny value to half of the specimen size, the compressive strength is expressed as:

$$f_c = f_0\left(1-\pi\frac{r^2}{a^2}\right) \tag{3}$$

According equation (3) the relationships among compressive strength, the volume fraction and specimen for 1 EPS beads in EPS concrete situation can be drawn as Figure 2.

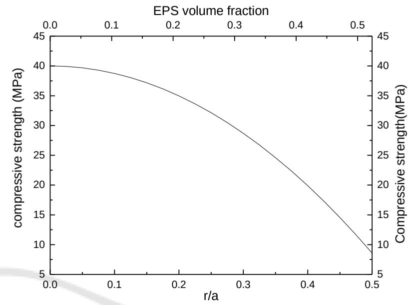


Figure 2: Relationship between *r/a* and compressive strength as only one EPS bead in concrete specimen.

Figure 2 shows that there is only 1 EPS bead in the specimen, and when *r/a*=0, the EPS concrete has the maximum compressive strength 40 MPa. When r/a increases, the compressive strength decreases gradually. In addition, the volume fraction of EPS beads increases as r/a increases.

2) when $\left(2+\frac{2}{\sqrt{3}}\right)r \le a < \left(2+\sqrt{2}\right)r$, $\left(\frac{1}{2+\sqrt{2}} < \frac{r}{a} < \frac{1}{2+2/\sqrt{3}}\right)$,

The compressive strength can be deduced as:

$$f_c = f_0\left(1-\frac{fix\left(\frac{3\varepsilon a^3}{4\pi r^3}\right)\pi r^2}{a^2}\right) \tag{4}$$

where *fix* is round function.

# 3 RESULTS AND DISCUSSION

Here the volume fraction of EPS bead is adopted as 5%, 20% and 40% to find the role of r/a on compressive strength according to equation (1), (2) , (3) and (4) respectively.

For $\varepsilon = 5\%$, the ratio of EPS bead to specimen should be $\frac{r}{a} \le 0.2285$. The relationship between r/a and compressive strength can be drawn as Figure 3.

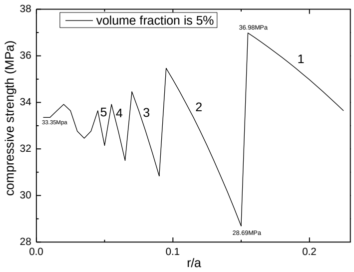


Figure 3: Relationship between *r/a* and compressive strength when $\varepsilon = 5\%$.

Figure 3 is the relationship between r/a and compressive strength as the EPS volume fraction is 5%, which corresponding to the loose packing model and the lines marked 1,2,3,4 and 5 stand for the total number of EPS beads in each direction of the maximum cross-section of specimen. Figure3 shows that the compressive strength sways up and down from the initial value of 33.35MPa. When r/a is less than 0.05, the deviation of compressive strength of EPS concrete is less than 1MPa. The maximum and the minimum compressive strength are 36.98MPa and 28.69MPacorresponding to 1 EPS bead and 2 EPS beads in each direction of the maximum cross section. In addition, in each number line zone, the compressive strength decreases with increasing r/a, that is, if possible, reducing the number of EPS beads in the maximum cross section area and r/a can increase the compressive strength.

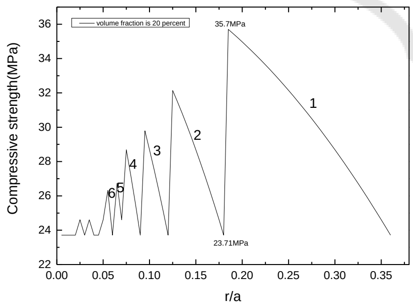


Figure 4: Relationship between *r/a* and compressive strength when $\varepsilon = 20\%$.

Figure 4 is the relationship between r/a and compressive strength when the EPS volume fraction is 20%, in which marked 1 to 6 lines stand for the total number of EPS beads in each direction of the maximum cross section area. In line 1, there is only 1 ESP bead in the maximum cross-section, and r/a ranges from 0.2 to 0.36. Similarly, in line 2, there are 2 EPS beads in cross section area, which r/a is between 0.125 to 0.18. In Figure 4, the maximum compressive strength and the minimum compressive strength are 35.7 MPa and 23.71MPa, respectively. When r/a value is higher than 0.05, the maximum compressive strength increases gradually until r/a reaches 0.18, but the minimum compressive strength is same as the initial value 23.71MPa. When in marked 1 line, r/a increase from 0.2 to 0.36, the compressive strength drops gradually from the maximum 35.7 MPa to the minimum 23.71MPa. Therefore, the compressive strength can be increased by adjusting r/a value.

Compared Figure4 with Figure3, it can be found that the maximum compressive strength drops only 1 MPa from 36.98 to 35.7 MPa, but the minimum compressive strength drops from 28.69 to 23.71 MPa as the EPS volume fraction increases from 5% to 20%.

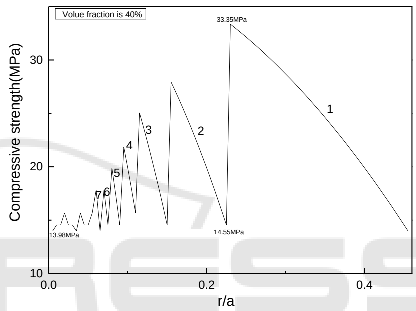


Figure 5: Relationship between r/a and compressive strength when $\varepsilon = 40\%$.

Figure 5 shows the relationship between r/a and compressive strength when the EPS beads volume fraction is 40%. When r/a is smaller than 0.05, the difference between the maximum and the minimum compressive strength is about 1 MPa. When r/a is bigger than 0.05, the difference between the maximum and the minimum compressive strength rises up to 19MPa as the total number of EPS bead in the maximum cross-section decreases to 1 EPS bead. When there is only 1 EPS bead in specimen cross section area, r/a can be ranged from 0.25 to 0.45, the compressive strength drops from the maximum 33.35MPa to the minimum 14.55 MPa. In addition, when there is only 1 or 2 EPS beads in each direction of specimen cross section area, the minimum compressive strength is also 14.55 MPa which is very close to 13.98MPa, and the difference between the maximum and the minimum compressive is 129% of the minimum compressive strength.

Compared Figure 5 with Figure 4 and Figure 3, it can be found that the maximum compressive strength drops little (36.98, 35.37 and 33.35MPa) as EPS beads volume fraction increases from 5% to 40%, but the minimum compressive strength decreases greatly from 28.69 MPa to 14.55 MPa which means that the EPS volume fraction can determine the minimum compressive strength and the maximum compressive strength of the specimen is relied on r/a. For the large specimen, r/a approaches to zero, and the effect of ratio of r/a can be neglected. However, for the small size specimen changing r/a value is a way to enhance its compressive strength.

## 4 CONCLUSIONS

Through studying, the following conclusions can be got:

1) When $\frac{r}{a} \leq 0.05$ , the influence of r/a on compressive strength can be neglected.
2) The minimum compressive strength decrease as the EPS volume fraction increases.
3) The volume fraction of EPS bead determines the minimum compressive strength of EPS concrete specimen, and the maximum compressive strength is determined by r/a.
4) When the EPS volume fraction is constant, adjusting r/a is an effective way to enhance the EPS concrete compressive strength.

## ACKNOWLEDGEMENTS

Thanks for the projects from Weifang University of Science and Technology, Grant No: 2018wksd009 and 2018wksd010.

## REFERENCES

Babu, D.S., Babu, K. G. and Wee, T.H., 2006. Cement and Concrete Composites, 28(6): pp. 520-527.

Babu, K.G. and Babu, D.S., 2003. Cement and Concrete Research, 33(5): pp. 755-762.

Bouvard, D., Chaix, J.M., Dendievel, R., Fazekas, A., Létang, J.M., Peix, G., Quenard D., 2007. Cement and Concrete Research, 37(12): pp. 1666-1673.

Chen, B., and Liu, N., 2013. Construction and Building Materials, 2013. 44(0): pp. 691-698.

Fu, G. and Dekelbab, W., 2003. Powder Technology, 133(1–3): pp. 147-155.

Laukaitis, A., Žurauskas, R. and Kerien≐, J., 2005. Cement and Concrete Composites, 27(1): pp. 41-47.

Ling, I.H. and Teo, D.C.L., 2011. Construction and Building Materials, 25(8): pp. 3648-3655.

Liu, Y., You, Z. and Zhao, Y., 2012. Construction and Building Materials, 37: pp. 775-782.

Miled, K., Le Roy, R., Sab, K., Boulay, C., 2004. Mechanics of Materials, 36(11): pp. 1031-1046.

Miled, K., Sab, K. and Le Roy R., 2007. Mechanics of Materials, 39(3): pp. 222-240.

Song, C.M., Wang, P., Makse, H.A., 2008. Nature, 453: pp. 629-632.