BRCORP
TECHNOLOGY | INNOVATION | INDUSTRY

*International Journal of*
*Advanced Structures and Geotechnical Engineering*
*ISSN 2319-5347, Vol. 02, No. 02, April 2013*

# Investigation of Styrofoam as Lightweight Aggregate

**BASHIR ALAM[1], ZAHID ULLAH[1], FAHEEM ULLAH JAN[1], KHAN SHAHZADA[1], SALMAN AFZAL[2]**
[1]*Department of Civil Engineering, University of Engineering & Technology, Peshawar, Pakistan*
[2]*Department of Civil Engineering, IQRA National University, Peshawar, Pakistan*
*Email: salmanafzalkhan@gmail.com*

**Abstract:** This research work utilized the laboratory evaluation of the performance of Styrofoam in concrete as lightweight aggregate by focusing on its ability to reduce dead load without significant reduction in compressive strength. Styrofoam particles of 0.50 inch-square sizes were used to partially replace (by volume) coarse aggregates. The study mainly focuses on the comparison of compressive strength and unit weight of concrete. Standard sized cylindrical specimens (6"×12") were prepared for this purpose. The compressive strength and unit weight of normal density concrete, prepared at mix design ratio of 1:2:4 (cement: sand: coarse aggregate) were used as yardstick for comparison with Styrofoam lightweight concrete.

***Keywords:*** *Styrofoam, Lightweight concrete, Compressive strength*

## 1. Introduction

Lightweight aggregate (clinker, pumice, shale, slate etc.) and chemicals have been used by many researchers for the development of lightweight concrete [1]. Lightweight concrete has remained a choice of designers due to the economy achieved in construction especially in the construction of high-rise buildings [2]. Lightweight concrete is prepared by either injecting a source of air within the concrete matrix in the form of a foaming agent, or by using lightweight aggregates [3].

The use of lightweight concrete increases the resistance of concrete structures to more dead loads at a reduced weight of the overall structure, thus enhancing the functionality, architectural outlook and erection [4]. Similarly, lager or longer precast concrete members can be prepared without adding to the overall weight of the concrete member [5]. This results in a lesser amount of columns and pier elements in a construction system which is easier to place at the desired location with fewer joints [6]. In bridges, this may permit the use of an extensive bridge deck which can provide additional lanes.

Styrofoam is a prevalent material for the use in thermal insulation of buildings during construction. Apart from insulation, Styrofoam is widely used as packing of food materials in storing and for protecting goods from vibration forces during the transportation phase [7]. It is treated as a waste product. The cell structure of Styrofoam consists of air up to 98% [8].

This research study focuses on the performance of Styrofoam (packing material) as lightweight aggregate and its ability to reduce dead load without sacrificing the strength. Styrofoam particles were used to partially replace coarse aggregate. Compressive strength and unit weight of normal density concrete (1:2:4) were used as benchmark for comparison with Styrofoam lightweight concrete.

## 2. Materials

*Styrofoam:*

Styrofoam, after they had been used as packaging tool, were brought in the form of long sheets and cut down to 0.5 inch-square sizes as shown in Fig 1. The physical properties of Styrofoam, used, were determined and are described in Table 1. The unit weight of Styrofoam obtained was 0.696 lb/ft$^3$.

*Fig 1. Styrofoam*

**Table 1.** Properties of Styrofoam

| Physical Properties | **Data** |
|---|---|
| **Size (in$^2$)** | 0.5 |
| Unit Weight (lb/ft$^3$) | 0.696 |
| Moisture content (%) | --- |
| Water adsorption (%) | --- |

*Aggregates:*
The properties of aggregates (coarse and fine) used, were determined and the required material tests were conducted and conformed to the ASTM requirements. Physical properties of coarse and fine aggregates are given in Table 2. Particle size distribution for coarse aggregate was also conducted.

**Table 2.** Properties of Aggregate

| **Properties of Coarse and Fine Aggregate** | |
|---|---|
| ***Coarse Aggregate:*** Property | Data |
| **Unit Weight (lb/ft$^3$)** | 81.48 |
| Absorption | 1.30% |
| Bulk specific gravity (Oven dried) | 2.70 lb |
| Bulk specific gravity SSD | 2.74 lb |
| *Fine Aggregate:* | |
| Fineness modulus | 2.9825 |
| Specific gravity SSD | 2.80 |

## 3. Experimental Program

In first batch of Styrofoam concrete mass, the conventional mix procedure was employed as was used for normal density concrete by mixing binding material and aggregates simultaneously. However it was observed that most of Styrofoam particles accumulated on the surface of mix because of their lightweight and did not mix properly. After that, the mixing of concrete materials and Styrofoam was done in a sequential manner.
Firstly, Styrofoam was added to cement and sand paste in its cut form. The mixing was continued until Styrofoam was mixed properly in the paste and uniform paste was seen. After that, coarse aggregates were mixed in the paste and well-mixed Styrofoam concrete mass was obtained. This mixing procedure proved to be appropriate for mixing Styrofoam concrete mix and was employed further in this study. The analysis of compressive strength of two different mixing procedures is shown in Fig 2.

## 4. Results and Discussions

Trial and Error approach was adopted to study the performance of Styrofoam as light weight aggregate in concrete. Coarse aggregate was replaced (by volume) with 0.50 inch-square Styrofoam particles. Standard size cylindrical specimens (6" × 12") were used to study the unit weight and compressive strength behavior of Styrofoam light weight concrete.

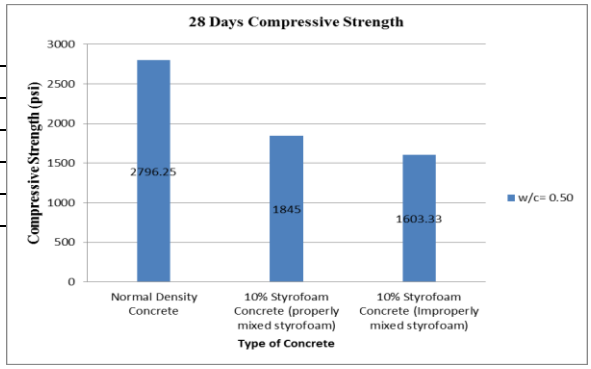


***Fig 2.*** *Effect of mixing procedure on compressive strength*

*Water-cement ratio:*
To study the effect of water cement ratio on Styrofoam, concrete trials were conducted with w/c of 0.50 and 0.45. It was observed that with reduction in water cement ratio the compressive strength increased significantly. The effect of water cement ratio on compressive strength is shown in Fig. 3.

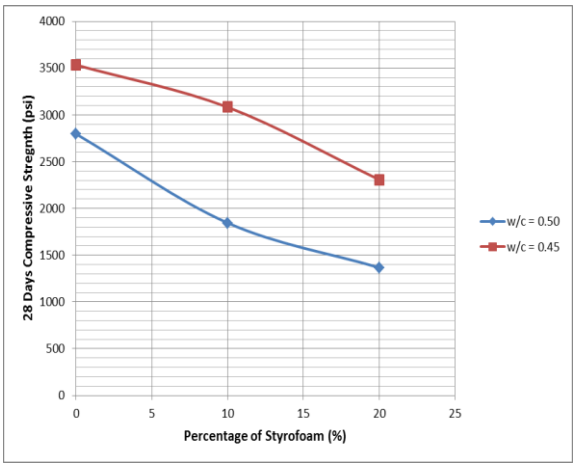


*Fig 3. Effect of water-cement ratio*

One of the advantage of using Styrofoam as light weight aggregate is its non-absorbent nature. Because of its non-absorbent a workable mix of Styrofoam concrete can be obtained at reduced water cement ratio which also enhances the compressive strength behavior of Styrofoam concrete. Fig 3 also shows that 28 days compressive strength of lightweight concrete having 20% Styrofoam was increased by 68%, by reducing water cement ratio from 0.50 to 0.45.

*Compressive strength*
For different percentages of Styrofoam concrete, 7, 14 & 28 days compressive strength, are shown in Fig 4.

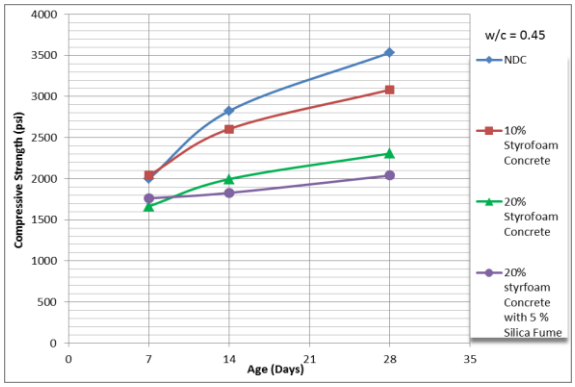


*Fig 4. Compressive strength*

The different series, shown, allowed the comparison of compressive strength with normal density concrete. All specimens were cured till test day to ensure that effective hydration had taken place. The red series shows that 7 days compressive strength of 10% Styrofoam concrete was approximately equal to that of normal density concrete however 28 days strength was 12.78% less than normal density concrete. The green series shows the compressive strength of Styrofoam concrete which contains 20% Styrofoam by volume. Its 28 days strength was 2307.71psi, 34.70% less than NDC which have 28days compressive strength of 3534.30psi.

**Table 3.** Percentage reduction in compressive strength and unit weight

| **Type of Concrete** | **w/c** | **Unit Weight (lb/ft$^3$)** | **% Reduction in Unit weight (%)** | **fc'** (psi) | | **%** Reduction in **fc'** |
|---|---|---|---|---|---|---|
| | | | | Age | Strength | |
| **Normal Density Concrete** | 0.45 | 123 | 0 | 7 days | 1998.43 | 0 |
| | | | | 14 days | 2824.84 | 0 |
| | | | | 28 days | 3534.30 | 0 |
| **10 % Styrofoam LWC** | 0.45 | 112 | 8.94 | 7 days | 2040.60 | -2.11 |
| | | | | 14 days | 2605 | 7.78 |
| | | | | 28 days | 3082.32 | 12.78 |
| **20 % Styrofoam LWC** | 0.45 | 101 | 17.90 | 7 days | 1665.66 | 16.65 |
| | | | | 14 days | 1995.33 | 29.36 |
| | | | | 28 days | 2307.71 | 34.70 |
| **20% Styrofoam LWC with 5% Silica fume** | 0.45 | 109.50 | 10.98 | 7 days | 1761.95 | 11.83 |
| | | | | 14 days | 1828.21 | 35.28 |
| | | | | 28 days | 2038.71 | 42.32 |

The fourth series shows the effect of silica fume on compressive strength of Styrofoam lightweight concrete. In this mix 20% coarse aggregate was replaced with Styrofoam by volume and 5% ordinary Portland cement was replaced with silica fume. It was observed that compressive strength was not only less than NDC but it was also less than the third series which contained only 20% Styrofoam. Its 28 days compressive strength was 42.32% less than that of NDC. The percentage reduction in compressive strength at different percentage of Styrofoam is given in Table3.

*Unit weight:*

Reduction in unit weight of concrete as a result of using Styrofoam is shown in Fig 5. The unit weight of normal density concrete obtained was 123lb/ft$^3$. As a result of 10% coarse aggregate replacement (by volume) with Styrofoam the unit weight reduced to 112lb/ft$^3$ while at 20% of Styrofoam it reduces to 101lb/ft$^3$.

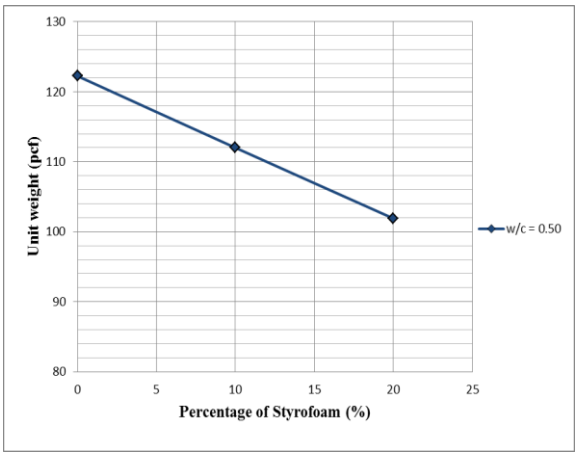


*Fig 5. Reduction in unit weight*

## 5. Conclusions

Based on the observations and testing performed on the Styrofoam Light Weight Concrete, the following conclusions were drawn:

- The compressive strength of Styrofoam light weight concrete having 20% Styrofoam reduced the unit weight to 101lb/ft$^3$ and the compressive strength was 2307 psi.
- The compressive strength of Styrofoam light weight concrete increased significantly by reducing water cement ratio.
- The compressive strength of Styrofoam concrete, having 20% of Styrofoam and 5% silica fume at w/c of 0.45 was 42% less than that of Normal density concrete. While unit weight was reduced by 10.98%. This showed that use of silica fume in Styrofoam concrete does not improve the compressive strength and is not economical to use.

## 6. Future work

The study of the behavior of Styrofoam lightweight concrete at further reduced water cement ratio 0.40, 0.35 etc. is needed in research activity. Moreover, study of the performance of Styrofoam as lightweight aggregate at particles sizes smaller than 0.50 inch-square i.e. 0.25 inch-square is also recommended.

## 7. References

[1] A. M. Neville. 1995. *Properties of Concrete – Fourth Edition*. Longman.

[2] Mohd Hilton Ahmad, Rohayu Che Omar, Marlinda Abdul Malek, Nurazuwa Md Noor, Sivadass Thiruselvam, "Mix Design of Styrofoam Concrete", Proceedings of ICCBT2008.

[3] S.H. Perry, P.H. Bischoff, K. Yumura, "Mix details and material behaviour of polystyrene aggregate concrete", Magazine of Concrete Research 43, 1991, pp. 71-76.

[4] Rudnai, G. (1963) *Lightweight concretes*. Budapest, Akademi Kiado.

[5] D.J. Cook, "Expanded polystyrene concrete", Concrete Technology and Design, New Concrete Materials, Vol. 1, Surrey University Press, 1983, pp. 41-69.

[6] Visagie, M. & Kearsley, E.P. (2002) Properties of foamed concrete as influenced by airvoid parameters. Concrete, 101, 8-14.

[7] Short, A. & Kinniburgh, W. (1978) *Lightweight concrete*, London.

[8] Short, A. & Kinniburgh, W. (1963) *Lightweight concrete*, Asia Publishing House.