Design of an optimum mix for Light Weight Compound Sandwich Wall Panel

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ABSTRACT: Increased demand for housing and buildings has led designers to seek for alternative construction techniques. The Light Weight Compound Sandwich Wall Panel is one such initiative. It consists of two fiber cement boards or calcium silicate boards which act as a reinforcement to the in-filled foam concrete which contains cement, sand, Expanded Polystyrene (EP) and fly ash. Hence, the foam concrete, which is a type of light weight concrete would contribute towards sustainable development with its cost effectiveness and optimized usage of resources. The research was aimed at identifying the optimum mix by replacing fly ash for concrete and EP for sand. Furthermore, in order to increase the sustainability aspects of the product, the possibility of replacing EP by recycled polystyrene was also explored. The decisions were based on the 7 day and 28 day strength results for the compressive and flexural tests.

1. INTRODUCTION

In the past, engineers practiced construction using conventional techniques. This included conventional design guidelines as well as materials. However, as of late, they have sought after alternative construction techniques and this could be attributed to the increased demand for housing and buildings. This is due to the requirement of massive amounts of building material and labor for conventional construction methods, which in fact have already crossed the boundaries of sustainability. In this context, Pre-cast building systems can exhibit a lot of promise with optimized use of material and labor, which in turn would reduce the use of natural resources.

This research paper is based on a case study for wall panels constructed out of Expanded Polystyrene. The proposed system will contribute towards sustainable development with its cost effectiveness and optimized usage of resources.

2. LITERATURE REVIEW

The proposed wall panel is to be constructed in the form of Light Weight Compound Sandwich Wall Panel. The demand for lightweight concrete in many applications of modern construction is increasing, owing to the advantage that lower density results in a significant benefit in terms of creating much more elegant and economical structures (Miled et al. 2003). Furthermore, previous research has also indicated satisfactory behavior in terms of thermal insulation, moisture resistance, durability, acoustic absorption and low thermal conductivity. (Chen et al. 2015)

Foam concrete is a type of lightweight concrete and hence, has the advantages of possessing a high flowability and minimal consumption of aggregate. Additionally, foam concrete has low densities typically ranging from 400 – 1600 kg/m^3 (Sayanthan et al. 2013). The foam concrete which is to be used for the proposed wall panel will consist of cement, sand expanded polystyrene and fly ash. It is expected that a certain proportion of cement and sand could be replaced by fly ash and expanded polystyrene respectively (to ensure gaining of adequate strength, albeit at a lower density).

However, the use of foam concrete in structural applications is quite limited due to its low compressive strength (Sayanthan et al. 2013). But on the other hand, since these wall panels would not be load bearing walls (since the house is expected to act as a framed structure), a compressive strength sufficient to carry its self-weight would provide a feasible wall panel. Furthermore, the wall panels should be able to withstand the lateral forces, especially due to wind loads and hence, the flexural capacity of the panels would also be critical.

The core materials of the panel play a vital, role in determining its mechanical and dynamic properties such as energy absorption and change of rate of strain etc. The material density has a significant influence on the mechanical properties of elements constructed out of expanded polystyrene. In fact, the compressive elastic modulus and yield strength increase with the density of expanded polystyrene. (Chen et al. 2015) . Generally, the density is controlled through the amount and density of light weight aggregate, which in this case is related to the said properties of expanded polystyrene. (Xu et al. 2011). As far as factors affecting the compressive strength of a wall panel are concerned, previous research suggests that for a given density, the compressive strength would increase with the reduction of the expanded polystyrene bead size. (Miled et al. 2003)

Furthermore, the workability of the light-weight concrete should be taken into account when designing the material mix. Too much of expanded polystyrene in the mix could reduce the workability due to the hydrophobic properties and the increased surface area of expanded polystyrene beads. There is the risk of segregation and collapse if the expanded polystyrene percentage is higher and this could in turn lead to lower degree of compaction and lower strength of the final mix due to the Most of these EPS lightweight concretes displayed good workability. (Xu et al. 2011).

According to previous research, a light-weight concrete mix which uses expanded polystyrene is expected to gain at least 80% of its compressive strength at 28 days by 7 days. This is greater than the general values for a normal concrete. (Xu et al. 2011).

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The stress- strain variation of an element constructed using light-weight concrete consisting of expanded polystyrene, when under compressive load has also been studied extensively, due to the compressibility of the expanded polystyrene beads. However, as illustrated in Fig. 1 , the variation of stress and strain for different mix constituent proportions of light-weight concrete was very similar to the expected variation for normal concrete. (Xu et al. 2011). Additionally, it has also been found that expanded polystyrene would not reach total stress relaxation.(Vaitkus et al. 2013)

Previous research suggests a ratio of 1:1:2 for cement to sand to expanded polystyrene with a water cement ratio of 0.4. However, this is for a density of 1250 kg/m^3 (Sayanthan et al. 2013). Meanwhile, for another research with a water cement ratio of 0.65, it was found that the compressive strength had increased with the increasing addition of fly ash. However the flexural strength decreased with the increasing addition of fly ash up to a 9% by weight (Wahab et al. 2013).

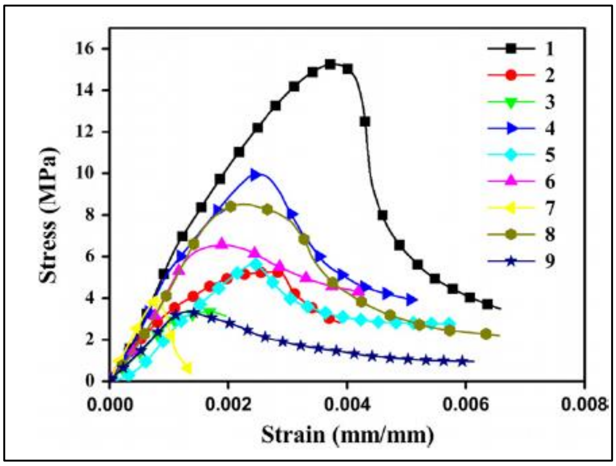

Fig. 1: Stress-strain diagram of EPS lightweight aggregate concrete (Xu et al. 2011)

3. PROPOSED WALL SYSTEM

The proposed wall panel consists of two fiber cement boards or calcium silicate boards which act as a reinforcement to the in-filled foam concrete (see Fig. 2).

Fig. 2: View of a wall panel

4. OBJECTIVES

Taking into account the above facts, a mix design would be carried out to identify the optimum mix for the Light Weight Compound Sandwich Wall Panel. Fig. 3 illustrates the state of a wall panel with excess Expanded Polystyrene, thus emphasizing the need for a detailed and methodical design process to ensure such failures are minimized. The main objective is to determine the optimum mix for the wall panel. The sub objectives of the design are to;

- determine the optimum fly ash content to ensure highest compressive and flexural strengths
- determine the optimum replacement percentage of Expanded Polystyrene with Recycled Polystyrene for the identified fly ash content.

Fig. 3: View of a wall panel with excess Expanded Polystyrene

5. PROPOSED PROCEDURE

As for the proposed test method for the first objective, the fly ash content would be increased from 0 % to 30 % in increments of 5% and for each case, sand will be replaced with polystyrene by 10%, 20% and 30%. The target density of the wall panel is 600kg/m^3.

The testing of compressive strength will be carried out by casting and testing cubes according to BS EN 12390-2 (2009) and the flexural strength will be determined for prismatic moulds using ASTM C348-14

As far as the construction of wall panels is concerned, it would be fully automated (see Fig. 4) and hence would reduce the workmanship defects of a typical wall construction.

Fig. 4: Equipment involved in the automated process of wall panel construction

6. CONCLUSION

The paper presents a literature review on the proposed wall panel system. The possibility of replacing a certain proportion of cement by fly ash and sand by Expanded Polystyrene and Recycled Polystyrene is explored by testing samples for compressive and flexural strengths, while targeting a density of 600 kg/m^3.

ACKNOWLEDGEMENT

The author wishes to acknowledge the advice and guidance provided by Prof. M.T.R. Jayasinghe, Prof. (Mrs.) C. Jayasinghe and Dr. C.S. Lewangama of University of Moratuwa and Mr. Neranjan Fernando.

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