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Behavior of a lightweight frame made with aerated slurry-infiltrated chicken mesh under cyclic lateral loading

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HIGHLIGHTS

- The seismic behavior of an aerated slurry-infiltrated chicken mesh structural system was evaluated by subjected a frame made with this material to cyclic in-plane lateral loading.
- The aerated slurry-infiltrated chicken mesh frame exhibited a ductile failure mode with a stable hysteretic behavior that provided for significant energy absorption capacity.
- The desired seismic performance of the aerated slurry-infiltrated chicken mesh frame can be attributed to the high specific surface area of chicken mesh, its desired mechanical interlocking within the cementitious matrix.
- Lightweight aerated slurry-infiltrated chicken mesh building structures provide qualities that are intermediate between wood and reinforced concrete structures.

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ABSTRACT

Aerated slurry-infiltrated chicken mesh was evaluated as a ductile and light-weight material for seismic-resistance building construction. An aerated slurry-infiltrated chicken mesh frame was subjected to cyclic lateral loading in order to assess its load-bearing capacity, ductility and hysteretic energy dissipation capacity. The frame exhibited a ductile failure mode compatible with its strong column-weak beam design. It also exhibited a desirable hysteretic energy dissipation capacity. Comparisons were made between the performance of this frame versus those of structural systems of similar geometric attributes made primarily of wood-based sheets. Semi-empirical models were developed for prediction of the structural behavior of aerated slurry-infiltrated chicken mesh. The structural performance of the frame made with aerated slurry-infiltrated chicken mesh under cyclic lateral loads was compared against those of lateral load-resisting systems of comparable geometric attributes comprising primarily of OSB and hardwood sheets. The aerated slurry-infiltrated chicken mesh structural system offers qualities that are intermediate between those of wood and reinforced concrete structural systems.
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1. Introduction

Aerated concrete is traditionally viewed as an insulating (non-structural) building material. A primary premise of the work reported herein is that a reinforcement system with high specific surface area would enable use of aerated concrete in structural applications. The high specific surface area and the confining role of such reinforcement is hypothesized to benefit the structural performance of aerated concrete. Construction with reinforcement systems of high specific surface area would be challenged by the congestion of reinforcement which is not favorable to convenient placement and consolidation of aerated concrete. An aerated slurry of high flowability was used in this work to thoroughly penetrate the congested reinforcement system, facilitating thorough consolidation and desired interfacial interactions with the reinforcement. This work chose chicken mesh (hexagonal 20-gauge galvanized poultry netting) as a steel reinforcement system of high specific surface area due to its broad availability across the world.

Concrete structures generally rely on frames as the primary lateral load-resisting structural systems [1–3]. Reinforced concrete frames can be designed to provide high levels of ductility and (hys-

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teretic) energy dissipation capacity for efficient resistance of seismic forces [4–7]. Aerated slurry-infiltrated chicken mesh can, due to the high specific surface area of steel reinforcement, provide distinctly high levels of ductility and energy dissipation capacity. The work reported herein evaluated the structural performance of an aerated slurry-infiltrated chicken mesh from under cyclic lateral loads. The data generated on the ductility, hysteretic energy absorption capacity and the lateral load-bearing capacity of the frame, accompanied with structural analyses of the frame, provide insight into the merits of aerated slurry-infiltrated chicken mesh as a robust building materials for construction of seismic-resistant building systems.

There has been growing interest in the use of lightweight aerated concrete as building envelope material. The desired balance of thermal and sound insulation qualities, fire resistance, strength, durability, cost, and ease of installation and maintenance of this material favor its broader use in building construction. Memon et al. [8,9] and Ng et al. [9] have reported data on the mechanical performance of autoclaved aerated panels. Low et al. [10] and Wakili et al. [11] investigated the thermal performance of these panels. Tanner et al. [12] and Costa et al. [13] investigated the failure modes and seismic behavior of autoclaved aerated concrete walls. The use of these walls in conjunction with steel frames has also been investigated under cyclic loading [14]. The use of fiber reinforced polymer composites towards seismic rehabilitation of autoclaved aerated concrete columns subjected to cyclic loading has also been investigated [15].

The innovative aspect of the work reported herein relates to transformation of an insulating lightweight (aerated) concrete into a structural material through reinforcement with a wire (chicken) mesh reinforcement of high specific surface area. A highly flowable aerated slurry is used to facilitate infiltration of the chicken mesh reinforcement with the lightweight cementitious matrix.

2. Materials and methods

2.1. Aerated slurry

Aeration introduces a homogenous system of fine air bubbles into the cement paste. This is accomplished using foaming agents that stabilize the air voids generated via agitation of the mixing water of slurry that incorporates the foaming agent [16–19]. Preparation of the aerated slurry started with production of foamed water. For this purpose, a foaming agent extracted from plants (saponin) blended with the mixing water at 1200 rpm rotational speed, using a mixing blade attached to a drill (Fig. 1). The foamed mixing water was then added to Type I Portland cement at water/cement ratio of 0.5. Mixing was accomplished in a mortar mixer for 2 min. Current investigations are carried out to produce aerated alkali activated cement based volcanic tuff [20,21].

The aerated slurry used to infiltrate the chicken mesh (Fig. 3b) comprised cement: water: saponin at 1: 0.5: 0.0006 wt ratios, with a bulk density in hardened state of 0.9 g/cm3. Based on trial and adjustment studies, it was found that an aerated slurry with viscosity of 1900.8 cp and yield stress of 68.2 is capable of infiltrating multiple layers of chicken mesh with the opening size considered in this investigation.

Cube specimens of plain aerated slurry with 50 mm dimensions were also prepared for performance of compression tests. The molded specimens were stored in sealed condition (>95% relative humidity) at room temperature) for 7 days, and then subjected to compression testing. The average compressive strength was measured at 5.01 MPa.

2.2. Chicken mesh

The chicken mesh considered in this experimental program (Fig. 2) comprised wire gauge No. 20 (with 0.88 mm diameter, 0.608 mm^2 cross sectional areas) configured hexagonally with wire spacing of 25 mm. Chicken meshes are available with different wire diameter and spacing. Commonly available chicken meshes are made with wires of different diameters; the spacing of hexagonally configured wires are generally increased with increasing wire diameter in order to provide comparable wire cross-sectional areas per unit width. Given the relatively large layers of chicken mesh that need to be infiltrated with aerated slurry, the preference in this investigation was for chicken meshes with larger wire diameter and spacing. Fig. 3 depicts the anisotropic structure of chicken mesh, which provides higher strength in the longitudinal direction and lower strength in the transverse direction.

2.3. Aerated slurry-infiltrated chicken mesh

Given the fine diameter of the chicken mesh wires, a relatively low volume fraction (e.g., 1%) of chicken mesh produces a relatively congested reinforcement system. As a result, cementitious materials with normal fresh mix rheology cannot be used in this application. The need to infiltrate multiple layers of chicken mesh led to the selection of a flowable slurry as the binder for use with chicken mesh reinforcement. Aerated slurry was used in this application to lower the density of structural materials for ease of installation and reduction of seismic forces. Aerated concrete is usually used as insulation and not in structural applications. It was hypothesized that the high specific surface area and the confining action of chicken mesh would enhance the mechanical performance of the resultant aerated slurry infiltrated chicken mesh to suit structural applications.

In chicken mesh, wires are oriented in different directions. Chicken mesh thus offers a high level of flexibility when subjected to tension, which is due to a tendency towards alignment of wires along the direction of tensile force. Their low stiffness excludes chicken mesh from structural applications. When placed within a matrix (aerated slurry in this case), however, the wires in chicken mesh are restrained against realignment by the matrix. Depending on the extent of this restraint, the tensile force-resisting capacity of wires would be mobilized from the beginning. This raises the stiffness of chicken mesh, which could translate aerated slurry infiltrated chicken mesh into a structural building material. Semi-empirical equations were developed to express the tensile and compressive strengths of aerated slurry infiltrated chicken mesh, as described below.

2.4. Aerated slurry infiltrated chicken mesh frame

The models presented earlier for predicting the flexural strength of aerated slurry infiltrated chicken mesh were verified using experimental results [22–28]

The tensile strength of aerated slurry infiltrated chicken mesh (σ_T) was expressed as follows:

$$\sigma_T = \alpha \rho f_y \quad (1)$$

where, ρ = area fraction of the chicken mesh wires (irrespective of their orientation) at a cross-section that is perpendicular to the tensile stress direction; f_y = yield stress of the chicken mesh wires (310 MPa); and α = an empirical efficiency factor which reflects the degree of restraint provided by the aerated slurry against realignment of wires (0.56 based on experimental results).

In compression, the composite behavior of aerated slurry infiltrated chicken mesh produces a compressive strength that can be expressed as follows:

Fig. 1. Preparation of foamed water.

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