10th Canadian Masonry Symposium, Banff, Alberta, June 8 – 12, 2005

EVALUATION OF LIGHTWEIGHT SAWDUST CONCRETE UNITS

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ABSTRACT

Lightweight sawdust concrete blocks manufactured entirely on an ad hoc basis from indigenous materials using only a hand-made steel plate mould were evaluated. These units were manufactured by combining locally available materials such as pit-run sand and clay, and untreated wood sawdust with cement and water. Consequently, these units exhibited a low compressive strength that would most likely make them unsuitable for hollow load-bearing masonry. However, when completely filled with a 25 MPa grout, two-high prisms exhibited an ultimate strength of approximately 16 MPa. Apart from this, it was found that these rather crudely manufactured units displayed some rather interesting characteristics that merit research in addition to the initial research present herein. The units, measuring 600 x 300 x 140 mm, while approximately equal to the weight of a standard 400 x 200 x 140 mm CMU, provide 2.25 times the wall surface area of the standard unit and require only 1.8 times the amount of mortar to fully install. Besides having advantageous properties relating to saw-cutting, nailing and screw attachments, it was found that hollow walls made of these units provide a brick veneer back-up as good as, or better than that provided by light gauge cold-formed steel studs.

KEYWORDS: lightweight, sawdust aggregate, brick veneer back-up

INTRODUCTION

Over the years, many attempts, some quite successful to a point, have been made to manufacture lightweight masonry units using indigenous materials in some cases and in other cases relying to a substantial degree on current technology at the time [1]. For example, Acker [2] developed a concrete masonry unit using expanded polystyrene beads to replace a portion of the much heavier sand aggregate used in the manufacture of standard masonry units. After several trials, a suitable lightweight unit with acceptable structural properties was developed to the point where its physical properties, apart from density, were comparable to those of traditional concrete masonry units. These new lightweight units, however, did not find their way into a substantial and viable market. This is mainly because the public perceived the new units as possibly not as robust or as durable as traditional units. Acker, among others, basically demonstrated that a sound lightweight unit is possible; whereas the change in human perception of such new products is a little more difficult, and perhaps requires much more research than the development of the unit itself. Others have experimented with various techniques, such as the use of aerated concrete [3], wherein tiny air bubbles are purposely infused into the mix providing spherical air pockets.

Perhaps the most commonly used lightweight aggregate is some form of wood waste, usually sawdust. The chemical incompatibility between wood residue and cement, arising from the presence in wood of a simple sugar known as lignin, results in a disturbance in the interaction between the wood and cement during the curing process [4]. The presence of mix water in the wood particles causes them to exude the lignin to the surface of the particle creating a surface layer that interferes with bonding between the particle and the cementitious materials, and thus, results in a somewhat deteriorated binding matrix. The chemical treatment required to eliminate this detrimental effect results in increased costs and consequent reduced marketing viability. On the other hand, simply soaking the wood particles in water for a period of time can reduce the amount of soluble matter and improve the binding mechanism to some extent. Some of the advantages of using a sawdust and sand aggregate include: reduced weight; can easily be sawed and nailed; good insulation value; low thermal conductivity; good resiliency; less tendency to fail in a brittle manner, obvious environmental advantages. Some disadvantages include: reduced fire rating; expansiveness in a moist environment; lower strength; pre-treatment of sawdust aggregate required to improve strength.

Because of proprietary concerns, the exact composition of the sawdust concrete units (SCUs) investigated in this paper is not known. However, all native and readily available materials, except for the cement, were used. The sawdust, generally derived from eastern spruce, was not pre-treated in any way. The clay/sand aggregate was chosen in a rule-of-thumb manner, wherein the clay and sand were proportioned so that when manually formed into an approximately spherical shape, gravitationally mobilized disintegration does not occur when the sphere is held in the open palm. It is believed that the composite sawdust/sand aggregate to cement ratio is about 3:1. Enough water is added to the mix to just permit incipient moulding workability. Vibration of the mould during this process is known to result in a marked improvement of unit compressive strength. The resulting density of the units tested was, on average, 930 kg/m^3.

BACKGROUND

It is pointed out here that this is not a missionary expedition but rather an expedition into an otherwise unexplored realm in the sense that there is no evidence of such crudely homemade SCUs having ever before been subjected to university–level research of this nature. Additionally, there was limited supply of both materials and financial assistance. As a result, the strict adherence to accepted testing procedures may be somewhat lacking. The motivation for the performance of this research was twofold, namely: (1) the manufacture and development of this type of SCU was privately funded and the undertaking was anticipatory of possible, but limited, government financial support in an effort to germinate a local industry; (2) testimonies to its probable future development and use include its use in the construction of two three-storey apartment buildings now extant, and an apparent genuine expression of interest in a variant form of the concept from abroad. Because of the nature of this undertaking, there were certain encumbrances which did not permit a free-flow of information and/or funding between the client and the research team. As a result, the research results presented herein may not appear to be complete or true to common practice. However, it is believed that the results as presented will be of considerable interest to many.

From previous work, it had been established that earlier versions of these particular hollow SCUs were quite weak in compression with an ultimate compressive strength in the order of only about 2 MPa. However, when vibration was applied to the moulds during the filling process, strengths were increased to between approximately 7 and 10 MPa. A typical SCU with four large cells and one smaller centrally located breaker cell is shown in Figure 1.

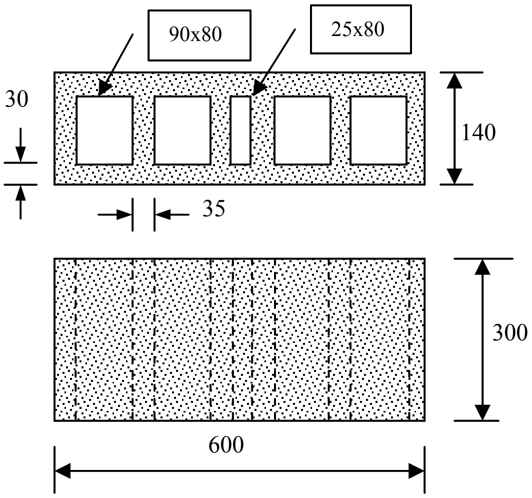

Figure 1: Sawdust Concrete Unit

The experimental evaluation presented herein includes the following:

1. Compressive tests of four, two-unit-high concrete-filled SCUs
2. Two series of pull-out tests as follows:
   a. Self-tapping sheet metal screws (38 mm, #8) embedded in:
      i. SCUs – 10 tests;
      ii. wood blocks – 3 tests;
      iii. light-gauge metal studs – 3 tests;
   b. Wood screws (38 mm, #8) embedded in:
      i. SCUs – 10 tests;
      ii. wood blocks – 3 tests;
      iii. light gauge metal studs - 3 tests;
3. Lateral wind pressure tests of three cavity walls as follows:
   a. BV/SCU cavity wall with wire truss bed joint ties;
   b. BV/SCU cavity wall with slotted channel/flat-bar ties;
   c. BV/SS cavity wall with slotted channel/flat-bar ties.

PRISM TESTS

Two-high prisms consisting of half-size SCUs and Type S mortar joints were completely filled with grout, hard-capped with a sulphur compound and tested in compression. The results of these tests are summarized in Table 1. Using average values from this table and a composite analysis including area effects and effects related to the grout density (2100 kg/m^3) and the sawdust concrete density (930 kg/m^3), it was determined that the stress in the SCU was ~11 MPa and that in the grout was ~25 MPa at ultimate.

Table 1: Compressive Strength of Grout-filled Sawdust Block Prisms

Specimen No.	Ultimate load kN	A_g mm^2	Stress at ultimate MPa
1	616	43 548	14.1
2	693	42 645	16.3
3	781	43 967	18.1
4	640	42 903	14.9
Ave.	683	43 266	15.9

PULL-OUT TESTS

One of the advantages of SCUs is that they can readily accept ordinary screws and nails. In the present research, both wood screw and sheet metal screw pull-out capacities were determined separately for SCU material, wood, and light gauge metal. Figure 2 illustrates a typical set-up used for pull-out tests, where a fastener is embedded in a SCU. In Series A tests, 38 mm, #8 self-tapping sheet metal screws were installed in SCU material (10 tests), wood block material (3 tests), and 20 ga. steel studs (3 tests). The average pull-out values were 0.69 kN, 1.33 kN, and 1.63 kN, respectively. Series B tests were a repetition of Series A except that 38 mm, #8 wood screws were used. For materials of SCU, wood, and 20 ga. metal, the average pull-out strengths were respectively, 1.63 kN, 3.24 kN, and 1.42 kN.

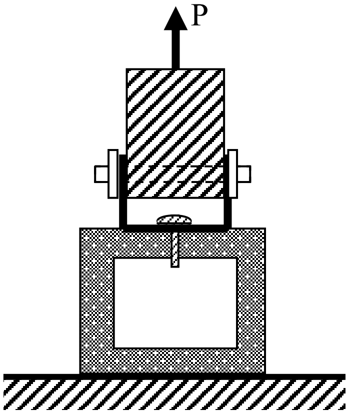

Figure 2: Pull-out test

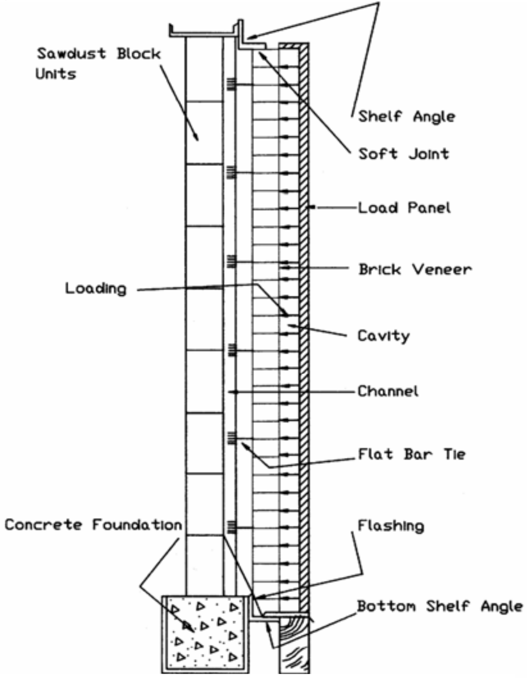

Figure 3: Wall Test Set-up

WALL TESTS

Three 50-mm cavity walls (Specimens W1, W2, and W3) each measuring 1220 mm long by 2900 mm high were laid up by certified masons using standard clay brick for the veneer wythes. SCU back-up wythes were used for W1 and W2 while a standard light gauge steel stud system was used as the back-up for W3. All walls were simply supported top and bottom as shown in

Figure 3 and were loaded uniformly using a pressurized air bag contained in a steel angle reinforced plywood box with dimensions similar to the wall specimens. With specimens in the mounted position, air bag pressure on the brick veneer, measured using an inclined manometer (Figure 4), was gradually incremented to ultimate. At each increment of load, wall deflections were monitored at 300 mm spacings along each vertical edge of the veneer and back-up and along the vertical centreline of the back-up wall for specimens W1 and W2. For Specimen W3 deflections were monitored at 300 mm spacings along both studs and along the centreline of the veneer.

Specimen W1 incorporated wire truss joint reinforcement ties, which extended from alternate bed joints in the back-up wythe into corresponding bed joints of the brick veneer wythe. The tie system used for specimen W2 consisted of 38 mm x 38 mm slotted channels screw fastened along the full height of the back-up (Figure 5). Channels were spaced horizontally at 600 mm c/c with 14 ga. flat bar inserts extending from the slots across the cavity and into corresponding bed joints of the veneer. A 20 ga. steel stud wall with studs spaced at 600 mm was used as the back-up for Specimen W3 with the same anchor and tie system as used for W2.

Figure 4: Test Walls

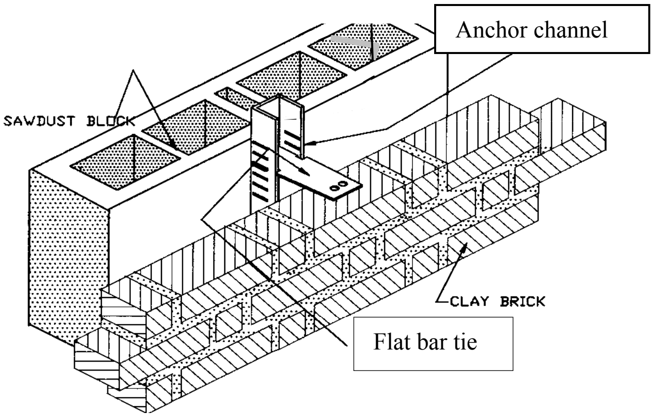

Figure 5: Slotted Channel/Flat Bar Tie System

TEST RESULTS

Specimen W1, which had a conventional wire truss tie system, developed a veneer bed joint separation near mid-height at 1.6 kPa followed by a similar occurrence in the SCU back-up at 1.8 kPa as seen in Figure 6. The ultimate capacity of the wall system was reached at 4.2 kPa when the wire ties buckled in combination with extensive cracking in the SCU back-up wythe.

Specimen W2, which included the tie system illustrated in Figure 5, developed mid-height bed joint separation simultaneously in the veneer and the SCU back-up wythes at 1.9 kPa. The ultimate capacity of the system, under the uniformly applied lateral pressure on the veneer, was reached at 8.8 kPa at which point extensive cracking and mortar joint separation were visually evident. The tie system had remained sound and intact throughout the test.

Specimen W3 consisted of a BV/SS system including the same tie system as used for Specimen W2. Separation of bed joints in the veneer near mid-height was first visually evident at 1.5 kPa. As loading progressed, extensive separation of the joints and cracks of the veneer were evident at 4.2 kPa. Ultimate capacity was reached at 5.1 kPa at which buckling of the webs of the steel studs had occurred. The results of all three wall tests are summarized in Table 2 and the deflection profiles are presented in Figures 7, 8, and 9.

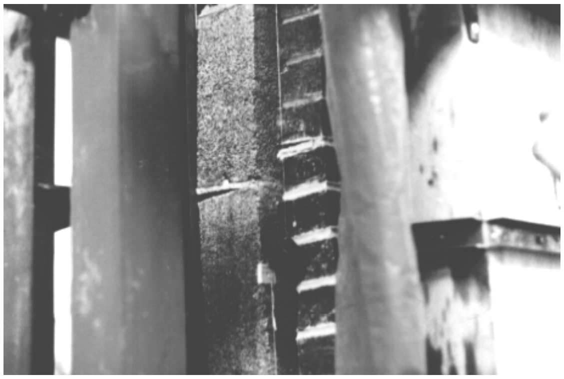

Figure 6: Mid-height bed joint separation

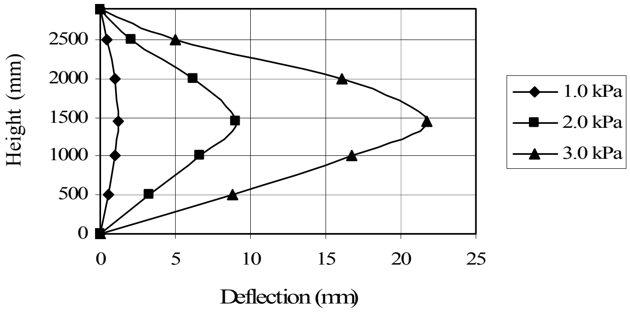

Figure 7: Deflection Profile – W1

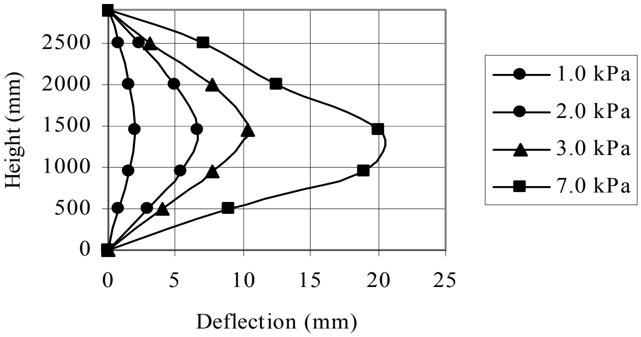

Figure 8: Deflection Profile – W2

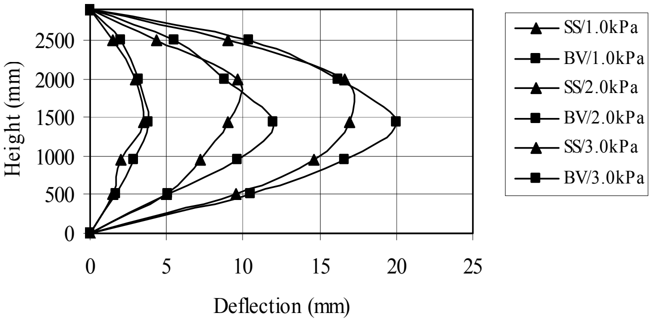

Figure 9: Deflection Profile – W3

Table 2: Summary of Wall Test Results

Test Event	W1	W2	W3
Initial joint separation in veneer (kPa)	1.6	1.9	1.5
Initial joint separation in back-up (kPa)	1.8	1.9	-
Ultimate pressure reached (kPa)	4.2	8.8	5.1

The differences in profile deflections between the brick veneer and SCU back-up are indiscernible, and are therefore, not shown in Figures 7 and 8, while in Figure 9, there is a noticeable separation of the profiles at each level of applied pressure. At higher pressures the net deflection of the brick veneer exceeds that of the steel studs at corresponding wall elevations. Considering this point and the values shown for W2 and W3 in Table 2 suggests that the SCU back-up displays an improved compatibility with the brick veneer over that which exists between the brick veneer and steel stud back-up. This improved compatibility, to a slightly lesser degree, is also apparent in the results for Specimen W1 as can be seen in Table 2. The relative initial secant stiffness values, k_1:k_2:k_3, up to 1.0 kPa for Specimens W1, W2, and W3, respectively, are approximately 1.0:0.6:0.3 while the relative corresponding ultimate strength values are approximately 0.5:1.0:0.6. The high initial stiffness of W1 was due to the use of continuous wire truss ties mortared solidly into alternate bed joints while the flat bar ties of Specimens W2 and W3 which fitted, characteristically, somewhat loosely into the slotted anchor channels, resulted in lower initial stiffness.

SUMMARY

The evaluation of sawdust concrete masonry units readily made from inexpensive indigenous materials of untreated random sawdust and commonly occurring clay and sand combined with cement and water was conducted. Two-unit-high SCU prisms were filled with grout and tested in direct compression to assess their possible use in load-bearing walls. The SCUs were also tested for pull-out strength of conventional wood and sheet metal screws and results were compared with the pull-out strengths of similar fasteners in sheet metal and ordinary wood. Finally, three double-wythe cavity brick veneer walls each measuring 1220 mm long by 2900 mm high were tested to ultimate under uniform lateral pressure. Two walls included hollow unreinforced SCU back-ups with either wire truss or flat bar/slotted channel anchor ties and the third included a steel stud back-up with flat bar/slotted channel anchor ties.

CONCLUSIONS

The preliminary research described above has resulted in the following essential findings:

- Two-unit-high grout-filled SCU prisms can attain a compressive strength as high as 16 MPa.
- The pull-out strength of conventional #8 wood screws in sawdust concrete material is equal to that of #8 sheet metal screws in 20 ga. metal.
- Back-up walls for brick veneer that are made of SCUs display overall better compatibility, ductility, and strength properties than are displayed by steel stud back-up walls.

It is emphasized that these findings are of a preliminary nature based on a limited number of test results. However, it is felt that they are encouraging to the point that additional research should be conducted in this area. An important preliminary finding is that SCU back-up wythes are more compatible with composite brick veneer action than are steel stud back-up walls. SCU back-ups are not only lightweight but also have more desirable acoustical and thermal insulation properties. It is believed that SCUs have better bonding properties with mortar and grout than exist with standard concrete units and that cementitious materials infiltrate the SCU material making it stronger. An added advantage is that there is no potential interactive corrosion, such as may be found between sheet metal screws, metal ties and galvanized steel studs. Finally, the system can be constructed entirely by masonry trade workers. All of these points go towards encouraging more research work in this area.

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