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THE DOCUMENTATION AND POTENTIALS OF ALTERNATIVE FILLERS IN CONCRETE BLOCK MASONRY UNITS

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ABSTRACT

Currently there is no concise source of information pertaining to the use of alternative fillers in concrete masonry units. This extends from a lack of information concerning commercially available alternative filler block types. This paper summarizes the information on different types of alternative filler blocks, which are presently available or being experimented upon. The analytical approach to the potential of an alternative filler in concrete masonry units is presented. The potential for a wide variety of fillers was identified. The emphasis of this project was on the use of recycled and/or waste products and the preliminary stage of this work is also presented. This includes the use of newspapers and rubber tires as the fillers.

INTRODUCTION

Most people in the construction industry are familiar with concrete blocks and their general uses. Concrete blocks are composed of water, Portland cement, and aggregates, or fillers, which are introduced to each other in specific proportions, mixed, vibrated into forms, and then dried either in the air or in autoclaves. Concrete blocks are often used for infill walls, as the structure in loadbearing walls, as fire separations, and in foundation systems. The performance of concrete blocks in all these applications can be modified and/or improved upon through experimentation. The potential alternative fillers that may be used in concrete blocks would seem endless, but care must be taken to determine the feasibility of these materials beforehand. Any time a different material is introduced to an existing mixture, a

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preliminary examination of the material properties, both separately and in combination, should take place. Ultimately, it is only through experimentation that the true nature of any alternative filler concrete block can be established.

THE CHEMISTRY AND PHYSICAL PROPERTIES OF CONCRETE

Properties Of Aggregates Or Fillers

Aggregates and fillers may take up as much as three quarters of the volume of a concrete block, but the actual percentage of aggregate, and the resulting physical properties of the block depend upon the overall properties of the aggregates. The important properties of aggregates are **shape** (affects workability of concrete and bonding surface area for the cement), **size** (controlled by grading and also affects workability of the concrete), **porosity** (porous materials lead to better bonding between the cement and the aggregate), **texture** (rougher textures can lead to better adhesion between the aggregate, or filler, and the cement), **reactivity** (any reactions will change the final properties of the aggregate and the cement, and the bonding process may be affected), **absorption** (a little absorption of water may improve the bonding between the aggregate and the cement, but removal of too much water will not permit the full hydration reaction to take place, leading to weaker concrete), **strength** (the strength and integrity of the filler are key to the strength of the concrete because the filler takes up a great deal of the concrete's volume), **toughness** (this is the aggregates ability to resist impact) and **resistance to wear** (due to its volume, fillers must be able to maintain their integrity over time).

All of these properties are important to the performance of the concrete masonry unit, based upon the bond of the aggregate to the cement matrix.

General Properties Of Concrete And Concrete Block

The main properties of concrete blocks are shape, density (size and mass), absorption, compressive and tensile strength, thermal RSI value, sound properties (STC class), fire resistance and durability. They are all linked in such a way that their combination determines the final performance of the blocks.

ANALYSIS CRITERIA FOR ALTERNATIVE FILLER CONCRETE BLOCKS

The feasibility to proceed with the experimentation on concrete blocks with the alternative filler is based upon the prediction of the concrete block's properties from the filler properties, such as shape, size, texture, porosity, availability, cost, porosity and absorption, toughness, chemical reactivity and molecular structure, thermal conductivity, compressive and tensile strength.

TYPES OF EXISTING ALTERNATIVE FILLER CONCRETE BLOCKS

General Introduction

The purpose of this section is to identify the various block types which have been

developed, and in order to provide an overall basis for comparison, information for standard concrete masonry units will be given for each of the criteria in the following section.
Research produced information for only six different types of alternative filler concrete block types. These types are the following:
Polystyrene bead block - produced by Sparfil International Inc.
Lightweight expanded slag block - Standard lightweight blocks manufactured by most companies in Southern Ontario. Manufactured as per O.C.B.A. standards.
Lightweight expanded shale block - produced by Trenwyth Industries Inc.
Sawdust Blocks - produced through research by Prairie Masonry Research Institute.
Wood chip block - produced by Durisol Materials Ltd.
Crushed glass block - produced through research by Newtonbrook Block and Supply Co. Ltd.
The information on several other fillers in concrete masonry units was either not readily available, or it was not available in English. A large amount of research seems to have been done in Germany, but the research has not been translated to English. The types of alternative blocks which fall into the above lightweight blocks category using pumice, are U.S. produced blocks using a lightweight filler known as Q-lite, lightweight blocks using fly-ash, and lightweight block using the ash produced by the incineration of garbage. The information on the latter block was not available.
The results of the comparative analysis can be found in Table 1 for a standard size hollow concrete block unit of 190mm x 190mm x 390mm (actual dimensions).

Observational Notes
The crushed glass block, developed by Newtonbrook, suffered from the alkali-aggregate reaction. The silica particles present in the crushed glass reacted within the alkali cement products. The problem was more one of durability, due to the reaction occurring over time, rather than a manufacturing problem. The shards of glass were exposed, which would make construction a difficult and potentially dangerous task. The third difficulty with the blocks occurred during manufacturing, when the process produced glass particulate air pollution, which created some discomfort.

The Durisol wood chip blocks are primarily used for highway barriers, and these are solid blocks. Durisol also produces the blocks in an oversized core format which is used as a form for wall systems. The cores may be reinforced and filled with concrete, similar to a normal masonry wall, but the wood chip block "form" provides improved thermal, sound attenuating, and fire resistance properties than a wall of equal width, composed of standard concrete blocks. Excellent sound and thermal properties of these blocks are due to the rough surface texture, which diffuses noise and contains air trapped spaces for thermal insulation. The Durisol blocks are also non-toxic, resist environmental degradation, and are recyclable, which is probably unlike any of the other alternative filler blocks.

The Sparfil expanded polystyrene bead blocks are also part of a complete wall system, and they have a special feature where there are two rows of cores in each block, which are offset from each other.

Table 1: Existing Alternative Concrete Masonry Unit Properties Based Upon 190mm x 190mm x 390mm Hollow Units.

BLOCK TYPE	FILLER TYPE	MASS (kg)	DENSITY (kg/m^3)	COMPRESSIVE STRENGTH GROSS AREA (Mpa)	RSI ($m^2.^0C$ /W)	STC CLASS	FIRE RESISTANCE (Hrs)	ABSORPTION (kg/m^3)
STANDARD	GRADED AGGREGATE	16.5	2094	8.4	0.21	49	1.8	225
SPARFIL	POLYSTYRENE BEADS	15.2	792	2.72	1.66	48	N/A	EST. AVERAGE
LIGHTWEIGHT	EXPANDED BLAST FURNACE SLAG	13.8	1641	8.4	0.30	49	2.5	320
LIGHTWEIGHT	EXPANDED SHALE	13.2	1669	7.4	EST. 0.30	EST. 49	2	240
SAWDUST	SAWDUST	9.66	686	9 - 11	0.45	41	1.77	EST. HIGH
DURISOL	WOOD CHIPS	<16.5	560	3.5	1.45 - >3.50	50	4-6 FOR WALL FORM	EST. MODERATE
NEWTONBROOK	CRUSHED GLASS	14.4	2067	15.1 (NET AREA)	>0.21	EST. 48	N/A	N/A

The lightweight blocks, in Ontario, are constructed according to the standards of the Ontario Concrete Block Association, but it should be noted that each company discovers its own manner of combining an alternative filler with the concrete block components, and this leads to blocks with differing properties, even though the same aggregate may be being used. Variations within certain block types may exist.

Potential Applications
The potential applications of alternative filler concrete blocks are:
Sparfil expanded polystyrene blocks: interior applications, infill walls, walls requiring enhanced thermal and acoustic properties, non-loadbearing conditions.
Lightweight expanded blast furnace and expanded shale blocks: interior applications, loadbearing and non-loadbearing conditions, no exterior applications due to absorption, infill walls, possible use in foundation walls if protected.
Sawdust Block: interior applications, loadbearing and non-loadbearing, capabilities, potential for foundation walls if protected, infill walls, walls requiring enhanced thermal and acoustic properties.
Durisol wood chip blocks: interior and exterior applications, generally non-loadbearing, except for grouted wall system where concrete is loadbearing element, infill walls, walls requiring improved thermal and acoustic properties, low impact applications unless wall is protected because wood chips tend to flake off and fire separations.
Newtonbrook glass blocks: interior applications, infill walls, low impact applications unless protected (due to exposed glass shards), non-loadbearing walls and possible use where thermal and acoustic properties are required.

POTENTIAL ALTERNATIVE FILLER CONCRETE BLOCKS

Alternative Filler Block Types
The potential fillers available for use in concrete block manufacturing are seemingly endless. Available fillers tend to fall under two broad categories which will be referred to as particulate fillers, such as the crushed glass filler, or fibrous fillers, such as plastic fibres. The first category has generally been explored more readily than the route of the fibre composite blocks because fibre is usually considered a reinforcement for improved tensile strength, while concrete blocks are typically thought of as compressive materials.
The true challenge and opportunity is to explore the potentials of products of material recycling, in order to create concrete blocks with properties similar to common blocks and at the same time conserve the natural resources.

Introduction Of Potential Fillers
Some of the potential fillers in the categories of particulate and fibrous materials are the following:
A. Particulate fillers
Rubber - particularly considering recycled tire rubber.
Cellulose particulates - shredded newsprint is such a material but it could be

potentially categorized as a fibre. It is an important consideration because paper can only be recycled so many times before it is unprintable. It is anywhere along the paper recycling process that it could be utilized in blocks.

B. Fibrous fillers

Glass Fibre

Steel fibre - this filler would probably only be considered as a means for improving the tensile strength of a concrete block.

Carbon fibre - there is the potential to create blocks that are stronger in tension, yet lightweight. One potential source for carbon fibre could be the automotive industry as carbon is a waste by-product of the manufacturing of engine parts.

Plastic fibre - consideration must be given to the nature of the plastic being used. Thermosets, such as polyester, are reaction based plastics which are generally heat resistant, while thermoplastics, such as nylons and polypropylene, are more susceptible to deform when exposed to higher temperatures.

Natural fibre (eg. Cellulose fibre) - careful consideration must be given to such materials because of their ability to absorb water, which can lead to dimensional changes of the filler in a concrete mixture during manufacturing, and later to potential moisture absorption.

These potential fillers have been chosen to represent the main types that are available. They will serve to demonstrate the filler properties and anticipated block properties in a broad manner. It should be remembered that even within the subcategories there can be a variation in the filer properties, and this analysis should be viewed as directive towards further analysis and experimentation.

Criteria And Property Analysis Of Fillers

The analysis of any potential alternative filler for concrete block is a speculative endeavor, when experimentation has not been previously performed. This analysis will be based upon concrete reinforcement research, basic chemistry knowledge, and specific research into the properties of the individual materials. Where ever possible, numerical results will be given for a particular criterion, otherwise, a qualitative measurement will be used.

Observational Notes

Rubber, as a potential alternative filler, has many properties which can make it appealing to use in concrete blocks. The rubber used in tires is referred to as an elastomer, which is composed of polymers of styrene and butadiene. The polymers are cross-linked by covalent bonds and sulphur acting as the bonding agent, through a manufacturing process called vulcanization. The polymer chains themselves are arranged in a generally random, amorphous structure, and this gives rubber its toughness and insulating properties. Yet, rubber is an excellent material for thermal storage. It has some major disadvantages as well. Rubber will compress under loading, and chemically, it is composed of molecules with covalent double bonds, which means that these sides are potentially reactive. It is for this reason that rubber can oxidize in air, and the result is a brittle hardening of the rubber. This reaction is further aided by a sensitivity to UV radiation.

There is only one problem associated with cellulose (paper), that is shared with other natural fibres, such as jute, sisal or cellulose, as well, which is its sensitivity to moisture and lack of durability in the alkaline environment of concrete. More unconventional process to the standard concrete block manufacturing must be sought. Glass fibre appears to be an excellent material to use in concrete blocks provided that alkali-resistant glass is used. Consideration for the material's brittleness due to its crystalline structure must be accounted for as well. The potential thermal and acoustic properties, along with its light mass, make this an interesting alternative filler.

Anticipated Masonry Unit Properties

Similar to the previous analysis, the examination of the potential properties of these alternative filler concrete blocks will be qualitative in nature. For the sake of comparison, the properties of a standard block will be used again as a reference. The resulting analysis can be seen in Table 2.

Observational Notes

In each of these cases there is not any chemical bonding between the filler and the cement products. The bonding is purely mechanical in nature, and therefore, the rougher the filler's texture, the better the bonding will be. In the case of the natural fibre block and the cellulose block, the mechanical bond may be stronger because the cement and water of the concrete would be able to penetrate into the voids between the fibres. In general, care must be taken in the manufacturing of the blocks to ensure that the volume occupied by the filler does not serve to inhibit the integral properties of the concrete block. The fibrous fillers, which are chemically neutral to the concrete, must therefore be essentially surrounded and encased in the concrete.
There are anticipated improvements in the thermal, acoustical, fire resistance and absorptive properties with the use of these fillers, the exception being steel. The rubber block also offers the intriguing potential for vibrational control because of the elastomeric capabilities of rubber.
What must be noted is that the fibrous fillers can provide the blocks with increased tensile strength in a manner similar to steel reinforcement bars in poured concrete. The main difficulty is that the strength of concrete block assemblies depend not only on the strength of the block but also on the strength of the mortar. The mortar has low tensile strength and the most vulnerable is the block-mortar interface. Once the crack forms at the interface, there is no tensile capacity. In order to make use of the improved tensile properties of new blocks, the mortar would have to be of adequate strength to work with the blocks in tension and thus improve the capacity of a wall assembly. Alternatively the blocks would have to be designed to be mechanically attached to resist tension without mortar.
Despite the potential advantages of increased tensile strength, the blocks offer potential improvements in the more traditional properties of concrete blocks, and this should be the initial point of experimentation.

Potential Applications

The potential applications for these proposed alternative filler concrete blocks are

Table 2: Anticipated Properties of the Alternative Concrete Masonry Units.

BLOCK TYPE	COMPRESSIVE STRENGTH GROSS AREA (Mpa)	DENSITY (kg/m^3)	MASS (kg)	RSI ($m^2 . ^0C$ /W)	STC CLASS	FIRE RESISTANCE (hrs)	ABSORPTION (kg/m^3)
STANDARD CONCRETE BLOCK	8.4	2094	16.5	0.21	49	1.8	225
RUBBER BLOCK	< 8.4	< 2094	< 16.5	>> 0.21	EST. 50	@ 1.8	> 225
CELLULOSE (PAPER) BLOCK	<< 8.4	<< 2094	@ 16.5	>> 0.21	EST. 50	< 1.8	> 225
FIBRE GLASS BLOCK	@ 8.4	@ 2094	<16.5	>> 0.21	EST. 50	> 1.8	< 225
STEEL FIBRE BLOCK	@ 8.4	> 2094	> 16.5	< 0.21	< 49	@ 1.8	< 225
CARBON FIBRE BLOCK	SLIGHTLY < 8.4	< 2094	< 16.5	> 0.21	> 49	> 1.8	<225
POLYESTER FIBRE BLOCK	SLIGHTLY < 8.4	<< 2094	< 16.5	> 0.21	> 49	> 1.8	< 225
NYLON FIBRE BLOCK	< 8.4	<< 2094	< 16.5	> 0.21	> 49	< 1.8	>> 225
POLYPROPYLENE FIBRE BLOCK	SLIGHTLY < 8.4	< 2094	< 16.5	> 0.21	@ 49	< 1.8	< 225
NATURAL FIBRE BLOCK	<< 8.4	<< 2094	< 16.5	> 0.21	> 49	@ 1.8	> 225

basically the same as those for the existing alternative filler blocks, but these fillers offer a greater variety of blocks to choose from, depending upon the specifics of the application. Each of the blocks has a potential to offer an unique characteristics.

TESTING OF ALTERNATIVE FILLER MASONRY UNITS

Introduction

Most of the fillers discussed in previous sections were available for this investigation. First two experimental filler materials used were shredded newsprint and ground rubber tire. The newsprint was obtained by shredding old newspapers that could be easily acquired and the ground rubber tires was obtained from National Rubber in Toronto. These fillers were then use to manufacture miniature blocks which nominally measured 5cm x 5cm x 10cm by Shouldice Cement Products Ltd. The manufacturer also provided the standard silica sand blocks which would be considered as the experimental control, and the source for comparison for all the other blocks. The filler blocks were made of the same materials and proportions as the standard silica block but the sand was partly replaced by the filler.

Testing Standards

The testing standards that were employed were CSA Standard A165 Series-94: CSA Standards on Concrete Masonry Units. This document then referred to ASTM Standard C140-91: Method of Sampling and Testing Concrete Masonry Units.

Tested Properties

The properties that were tested, as outlined in the ASTM Standard C140-91, were compressive strength, moisture content, density, and absorption.

Experimental Procedures And Equipment

The experimental procedures were those outlined by ASTM Standard C140-91, with the exception of the sampling procedure. There were 4 blocks, 3 were used for the compression test and one was used for the absorption test. The newsprint blocks were excluded from the absorption due to their lack of integrity.

The first step in the investigation was to weigh each of the blocks to record their mass with their regular moisture content and to record dimensions of each block. The absorption tests were performed next.

The samples were then hard capped and tested in the compression machine (Riehle Ka-400), commonly used for compression tests on concrete cylinders.

Test Results And Discussion

The compressive strength and other tested properties are given in Table 3. Based upon the relationship between the compressive strength of a full size block and a miniature block of similar mix proportions, the size factor was determined.

The apparent problems with the newsprint blocks (the low compressive strengths and the lack of block integrity) were probably due to several reasons. The first

Table 3: Experimental Test Results and Equivalent Full Size Results.

BLOCK TYPE	NET COMPRESSIVE STRENGTH MINI BLOCK (Mpa)	GROSS COMPRESSIVE STRENGTH MINI BLOCK (Mpa)	ESTIMATED NET FULL SIZE COMPRESSIVE STRENGTH (Mpa)	ESTIMATED GROSS FULL SIZE COMPRESSIVE STRENGTH (Mpa)	ABSORPTION (kg/m^3)	MOISTURE CONTENT (kg/m^3)	DENSITY (kg/m^3)
STANDARD	11.6	8.15	17.6	12.4	192	11.8	2018
75% Q-LITE	4.31	2.89	6.55	4.39	248	45.2	1253
45% Q-LITE	5.03	3.47	7.65	5.27	274	42.2	
PUMICE	3.71	2.58	5.64	3.92	163	18.8	1431
50% RUBBER	N/A	N/A	N/A	N/A	246	18	1425
35% RUBBER	3.56	2.47	5.41	3.75	257	19.7	1092
15% RUBBER	1.37	0.95	2.08	1.44	185	24.7	1815
NEWSPRINT	0.021	0.014	0.032	0.018	N/A	N/A	N/A

being that the individual filler particles were much too large for the size of the molds that were used. The newsprint should have been shredded into particles which were 3mm in width or less. The particle size which was used varied from 1cm to 3cm in width. The larger particles would probably have been better suited for the manufacturing of full sized concrete masonry units. The second problem was that the newsprint required more water due to its ability to absorb large amounts of water. That particular property of newsprint would also lead to dimensional changes in the mixture during the initial manufacturing process and to weaker block due to the water absorption during hydration. Perhaps the newsprint should have been saturated with water before it was introduced to the cement and sand in the mixture. The third major problem was the volume of newsprint which was used. Fifty percent was much too high. Perhaps an upper limit of approximately forty percent would produce better results.

The newsprint was not tested for its absorptive properties due to its poor integrity. A block with more structural integrity would be required to attempt such a testing procedure, and even then there are no guarantees that the block would maintain its form after being submerged for 24 hours.

The volume problem was also encountered with the recycled rubber blocks. The 50% rubber block was too elastic in nature. This was first noted in the manufacturing when the blocks expanded in the molds after a compressive force had been applied. A material such as rubber does not chemically bond with the cement in concrete, and since rubber is an elastomer, the strength of the block is largely due to the concrete in the block. In the fifty percent rubber block, the volume of rubber impeded the properties of the concrete. It appears that this block failed due to lateral strains caused by compressive deformation when the block was loaded. The results for the 35% rubber block were much more encouraging. The results of these blocks were similar to those of the pumice which is used as a lightweight block. The 15% rubber block was expected to result in the increased compressive strength of the unit but the experiments showed otherwise. At this point those results can not be explained.

The absorption results for the rubber blocks seemed quite high for a material that does not absorb water. This trend can probably be attributed to the volume and packing of the rubber filler in the block. The elastomeric properties of the blocks probably created small air pockets as they de-compressed in the molds during manufacturing. The density of the 35% rubber block is also quite a strange result. One should expect that it would be greater than the 50% rubber block density, but it is not. Once again this can be attributed to the size of the blocks and the packing of the mixture during manufacturing.

It should be noted that the wide variation in results is unavoidable, due to the size of the blocks.

Potential Applications

All blocks types summarized in Table 3 can be used for interior applications only, due to absorptive properties, non-loadbearing conditions or light load conditions, circumstances requiring lightweight units and infill walls. Rubber and newsprint blocks can further be used where improved thermal and acoustic properties are important.

Rubber block can further be used where improved vibrational properties are required.

CONCLUSIONS

It has been demonstrated that there are a large variety of potential alternative fillers to be used to manufacture alternative blocks, which may improve some of the general properties of the blocks that are presently used.
Firstly, if the miniature blocks are to be used, it is important to determine the relationship between the test results on the miniature and full scale blocks of the same proportions.
Secondly, the untreated newsprint can not be used to obtain blocks with any integrity.
Thirdly, it is necessary to investigate further the effect of the percentage of the rubber tire filler on the block' behavior. Also it is important to explain the discrepancy in the behavior of 35% and 15% rubber tire blocks from the expected behavior.
Fourthly, it is necessary to determine the thermal, acoustical, vibrational and fire properties of these new blocks.

REFERENCES

1. Clauser, H.R., Industrial and Engineering Materials, McGraw-Hill Book Co.,New York, U.S.A., 1975.
2. Drysdale, R.G., Amid, A.A., and Baker, L.R., Masonry Structures, Behaviour,and Design, Prentice Hall, Toronto, Canada, 1993.
3. Goyal, A., Rashwan, M.S., Hatznikolas, M.A., and Zervos, "Structural performance of cavity walls constructed with units containing sawdust and shear connected to the brick veneer",Canadian Journal of Civil Engineering, vol.21, Oct. 1994, pp.576-584.
4. Hannant, D.J., Fibre Cements and Fibre Concretes, John Wiley and Sons Ltd., New York, U.S.A.,1978.
5. Kosmatka, Steven H., Panarese, William C., Allen, Gerald E., and Cumming, Stanley, Design and Control of Concrete Mixtures, 5th metric ed., Canadian Portland Cement Association, Ottawa, Canada, 1991.
6. Neville, A.M., Properties of Concrete, 3rd ed., Longman Scientific and Technical, New York, U.S.A., 1981.
7. Porterfield, William W., Inorganic Chemistry: A Unified Approach, Addison-Wesley Publishing Co., Reading, Massachusetts, U.S.A., 1984.
8. Solomons, T.W.G., Organic Chemistry, 3rd ed., John Wiley and Sons, New York, U.S.A., 1984.
9. Swamy, R.N., ed., Concrete Technology and Design: New Reinforced Concrete, vol. 2, Surrey University Press, Glasgow, Scotland, 1984.
10. Toon, Ernest R., and Ellis, George L., Foundations of Chemistry, metric edition, Holt, Rinehart and Winston of Canada, Ltd., Toronto, Canada, 1978.
11. Young, John, Designing with GRC, The Architectural Press, London, Eng., 1978.

12. Durisol Materials International Ltd., Product Literature, Noise Barrier Wall System and Wall Form System.
13. ASTM Standard C140, American Society for Testing and Materials.
14. CSA Standard A165 Series-94, CSA Standards on Concrete Masonry Units, Canadian Standards Association, Toronto, Canada, 1994.
15. Ontario Concrete Block Association, Concrete Block - Metric Technical Manual, Toronto, Canada.
16. Canadian Construction Materials Centre, NRC-CNRC Registry of Product Evaluations, Summer 1994, IRC, Ottawa, Canada.1