Cob Research Institute (CRI) Interim COB TECHNICAL WHITE PAPER

A research project dedicated to making cob legally accessible to the public

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ABSTRACT

Cob is a valuable historically proven method of earth building. North America building regulation does not understand or recognize cob as legitimate. Consequently, cob is prevented from being used for construction in nearly all of the U.S. & Canada. To correct this, a cob building code needs to be developed and accepted by the existing North American building regulatory system. To create an effective cob building code, a full understanding of the existing technical knowledge of cob is needed. CRI is conducting research to find and compile technical information related to Cob. To date more than 230 resources have been found, and approximately 30 have been reviewed. Much remains to be done to complete the project. This paper is an interim overview of the research.

A HIGHLIGHTED HISTORY OF COB *reference 19*

Earth as a construction material has been used on every continent and throughout human history. "Cob" (the English term for mud wall construction) is direct shaping of plastic earth to build walls, and uses no forms, bricks, nor structural framework. Cob-like wall building appears to have originated in 11th century North Africa. Several forms of similar earth building are known under different names throughout most of the world. Cob in it's various forms has been used in Europe since the 12th century, Cob was the norm in parts of Britain by the 15th century and in widespread use by the 19th century. In the late 1800s industrial brick and transportation ended cob's practical use. Cob building then became considered primitive and backward and it's use was in decline. There was virtually no new cob construction until the 1980s, and traditional builders took much of their specialized knowledge with them to the grave. By the 20th Century, many long-neglected cob homes needed repair, causing a resurgence of interest in traditional building techniques. Restoration of ancient cob buildings became the advocate for the contemporary reintroduction of cob as a technique. Public attitudes changed and traditional cob cottages became valued as historical and picturesque. Enough traditional information had survived to allow a cob building revival in England in the 1990s. Early British building regulations (the 1842 1st National Building Act) did not recognize cob. Regulation slowly changed over the next 150 years until 1985 with adoption of the national Building Regulations, of which Regulation 7 (Materials) stated that **"any material which can be shown by experience such as a building in use, to be capable of performing the function of which it is intended" is satisfactory**. Thus the existence of an existing historic fabric of Cob in England made it once again possible for Cob to be constructed in the UK.

THE DEVELOPMENT OF 'OREGON COB.

In the early 1990's, the Cob Cottage Company in Oregon, working from the model of British cob, developed contemporary '**Oregon cob**.' Cob builders in previous centuries had to use whatever soil was on hand with little or no amendment. Modern transportation allows importing sand or clay as is needed to make a hard, stable cob mixture. Grain straw, formerly highly valuable, is now a readily available low cost agricultural waste product. Oregon Cob differs from traditional in the quality of ingredients and the proportions of the mix, and contains a high proportion of coarse sand and long, strong straw. These components strengthen the earthen mass and control cracking as the cob drys. Soils vary from site to site and Oregon cob mix proportions always need to be carefully tested before a wall is built. The development of Oregon Cob has enabled the contemporary emergence of cob as significant way to build.

COB AND SUSTAINABILITY

The essence of sustainability is "meeting the needs of the present without compromising the ability of future generations to meet their own needs." *reference 7* Comparing the **EMBODIED ENERGY and TREE USE of cob vs. standard wood frame** gives illustration of cob's sustainability. The extraction, processing, manufacture and transportation of the materials required to build standard wood frame construction uses **SIX TIMES MORE ENERGY THAN COB**. Tree use is another measure of sustainability. The construction of a 1000 s.f. **wood frame house** uses **13 trees** measuring 22" dia x 100' tall, appx 6500 b.f. of lumber. A 1000 s.f. **cob home with earth floors** requires just **three trees,** approximately 1500 b.f. lumber to frame the roof. Cob uses **ONE FOURTH THE LUMBER** as wood frame construction. *reference 13*

Other sustainable qualities of cob are reducing CO_2 emissions in production and use. Cob also gives the more subtle sustainable qualities of eliminating the many toxins involved in standard construction materials thereby significantly improving indoor air quality. *reference 5*

THE BUILDING CODE AS A BARRIER TO THE CONTEMPORARY USE OF COB

For cob buildings between 100 and 400 years old, specifications, building inspections, quality controls, and details of the performance of the material, would not have applied. Common sense, experience, and a feel for the material, would have been the main guidelines. *reference 19*

Contemporary cob is currently not recognized or understood by the International Building Code. In North America there is no cob specific building code. As a consequence, building legally with cob is restricted, problematic, and potentially very expensive. Currently, there are only four pathways to building with cob in North America, these are:

BUILD SMALL - The IBC and most local building codes in North America allow small structures of 120 square feet floor area to be constructed without building permits. The IBC does require such small structures to be build "per code", and not be used as habitable structures;

BUILD OUTLAW - without building permits. In rural locations where cob is not allowed, people build illegally in hopes that their structures may not be detected by local building enforcement;

BUILD IN LOCATIONS THAT HAVE "OWNER BUILDER CODES". California legislation provides a Limited Density Rural Owner Builder Code which allows rural construction of residences with a set of specific relaxed code and use requirements. Amador, Mendocino, Humboldt, Nevada and Marin Counties have adopted this legislation and allow cob structures with minimal code compliance requirements. Cochise County in Arizona, and Island County in Washington are other locations that allow cob building, although the requirements in these locations have not been researched for this paper. The Building Departments and Supervisors of these counties are to be much commended for their farsighted understanding of the needs of owner builders;

BUILD UNDER THE ALTERNATE MATERIALS AND METHODS (AMM) SECTION OF THE IBC. This approach requires professional structural engineering on a case by case basis which must be repeated for every new cob project. Securing AMM building permits is possible in most locations, but It is an expensive process requiring tenacity and patience on the part of everyone involved. AMM is currently the only means of building legally with cob in most of North America.

AN OUTLAW BUILDERS EXPERIENCE *reference 16*

Engineering notes for permitting an outlaw cob house in Sonora County, Ca.

An unpublished narrative of obtaining a building permit for an outlaw cob house built in rural Sonora County. Constructed without building permits circa 1995, the project was red-tagged by the County Building Department . In order to obtain a post construction building permit and legalize the structure, the owners were required to obtain engineering and ultimately modify the building to meet the engineer's structural requirements. An example of why a cob building code is needed. In addition, the reference gives a brief description of the experimental testing of 1/12th scale model cob structures.

ONE ENGINEER'S APPROACH TO AMM STRUCTURAL DESIGN. *reference 6*

Anthony Dente, Structural Engineer: "We conduct our design as primarily based in the US code while doing everything we can to abide by the rules in the New Zealand Earth Building Standards. We utilize strength values based on the currently available research from: Oregon University; University of San Francisco; and the University of Plymouth England. We take test data, verify that our materials are similar by requiring field testing, and add appropriate safety factors. Then we use those strength(s) to conduct the calculations.…..NZ specific ….. seismic zones.….. and how their lateral codes translated to ours…." Is a subject needing additional research.

SEISMIC STRENGTH OF COB - 2008 BA Engineering thesis at University of Technology, Sydney, Australia *reference 2*

The building & seismic testing of two (2) 1:2 scale structures using Oregon cob. The test structures were built in-situ in the Structures Laboratory of the University of Technology, Sydney, Australia. The incremental shake table testing of the two structures to the forces of a simulated M7.7 (M7.7ES) El Salvador earthquake was unable to damage both unreinforced and bamboo reinforced wall specimens. A further Sine Sweep test to 200% of the M7.7ES did produce cracking in the unreinforced wall, but was unable to damage the bamboo reinforced wall other than the minor the failure of one wall hold down attachment. As a result the thesis authors concluded that, based on the test results, both unreinforced and reinforced Oregon cob walls are suitable for construction in locations subject to severe earthquakes. In addition, Dr. Li, the academic who carried out the earthquake simulations, has expressed the opinion that,

" cob is many times stronger than mud brick" .

2004 University of British Columbia SHAKE TABLE TEST *reference 3*

A shake test at UBC of a 1/2 scale cob structure. The test was to determine the seismic performance of a 6' diameter structure, with 7" thick 4.5' tall walls with a door opening and a small window. The test simulated the 7.4 richter Landers Mojave quake in California and caused only minor cracks in the circular wall. A second simulated 9 richter event test caused: diagonal cracks radiating from the corners of the door, a horizontal shearing failure (probably due to cob lift layers not well integrated). Thereafter, the walls fractured and large chunks of cob fell outward away from the building. No large cob chunks fell inward. There was considerable rocking of the building from side to side which points to the importance of keying and tying down the building well to the foundation. Dr. Carlos Estuardo Ventura, P.E., P.Eng. of the UBC Faculty had this email comment:

"That was a very small project with a very limited scope and funding, so our work was only limited to the tests that you saw. Unfortunately, we did not receive additional funding for more detailed studies and we had to abandon the project."

COMPRESSIVE STRENGTH, MODULUS OF RUPTURE, AND FLEXURAL STRENGTH OF COB references: 1, 4, 9, 13, 15, 16, 17, 18

The strength properties of cob have been studied by several researchers. The results obtained vary and are an indication of the need for a coordinated cob research program.

Cob is a mixture of soil, sand, straw and water. The laboratory compressive strength of a cob mix depends on many factors. The mix soil: its classification, clay content, liquid limit, plastic index. The mix sand: % in the mix, particle gradation, angularity (particle shape). The mix straw: % content, length, type of straw, orientation in the test sample. Water content: wet mix volume of water, plastic mix % water, dried wall % moisture.

Of the cob test samples produced by experienced builders, all mixtures were near the range of water contents for which the soil achieves plastic state. This means that experienced cob builders had a good sense of when the soil achieved plasticity.

COMPRESSION TEST RESULTS

Data Source		**Ultimate Compression**	
		Tests Method	**Average (psi)**
Pullen and Scholz 2011		ASTM C 39	102
Rizza and Böttger n.d.	Conventional Mix	Based on standard 4”x8” concrete test cylinders	88
	Long straw		41
	Chopped straw		76
Miccoli, Müller, and Fontana 2014		EN 1052-1 with small walls	231
Saxton,1995		ASTM C 39	145
Misha Rauchwerger Kleinfelder Labs,		Based on standard 6”x 12” concrete test cylinders	120
Dani Mouawad Summit DE Lab		ASTM C 39	193
Akinkurolere, et al		Unspecified ASTM & British Standards using a 38 mm dia. compression disc	87

EFFECT OF SAND AND STRAW CONTENT ON THE STRENGTH OF COB

Research of cob mixes indicates that a high sand content produces a higher compressive strength, while a high straw content produces a lower compressive strength. Conversely, a high content of well integrated straw produces a high bending / rupture strength. Empirical evidence shows that linear orienting of straw along the length of a cob beam produces a greater spanning quality.

COMPRESSION TESTING SAMPLE SHAPE AND DIMENSIONS.

Standard ASTM tests are not designed for cob. The straw functions in a wall condition and this brings into question the use of concrete cylinder test samples. For cob compression testing, CRI is considering using a 12” cube sample standard as this will replicate the actual straw to wall width used in construction. Research to establish a compression test coefficient to predict the flexural / rupture strength of a cob mix concluded that coefficient test results are variable, unreliable, and dependent on the dimensions of the compression test sample. *reference 19*

FLEXURAL AND RUPTURE TEST RESULTS

Data Source		**Flexural Strength and Modulus of Rupture**	
		Tests Method	**Average (psi)**
Pullen and Scholz 2011		ASTM C 78	25 (modulus)
Rizza and Böttger2017	Conventional Mix	midspan flexure of 2 x 2 x 6 beams	142 (modulus)
	Added long straw		78 (modulus)
	Added chopped straw		115 (modulus)
Misha Rauchwerger Kleinfelder Labs		ASTM C293	105 (strength)

NOTE: The variation in test results supports the need for coordinated comprehensive testing.

SHEAR STRENGTH OF COB

The research for this paper has found no literature for in-plane shear testing of cob walls. The seismic testing at UTS in Australia (*reference 2)* gives evidence of a cob wall’s ability to resist both in-plane and out-of-plane seismic loads, but there is apparently no shear strength data for in-plane or out-of-plane cob. CRI is currently planning to test a set of 3 to 6 cob wall panels for in-plane shear loading in the Fall of 2018.

ANCHOR EMBEDMENT IN COB *reference 12*

Research of mechanical behavior of grouted anchors for earthen materials. While the research was of bond strength between lime based grout plug and an earthen materials interface (earth block masonry, rammed earth and cob). The conducted tests proved that the use of nuts screwed on steel anchor profiles strongly influenced the pull-out capacity. Embedded rods with nuts showed higher pull-out capacity. It is important to underline that the performances of plug embedded rods with nuts in cob were influenced by rough surface at the cob substrate. The non homogeneous surface caused a limited interlocking mechanism and allowed to reach as pull-out capacity about 54% higher than in earth block masonry results. For the anchors considered, the presence of nuts played an important role.

FIRE RESISTANCE AND FLAMMABILITY *references 4, & 14*

"Earth walls do not burn" was the conclusion of an earthen structure fire rating test by the Australian National Building Centre. A 400mm to 600mm (16" to 24") cob wall has a minimum fire resistance of 2 hours. In the German standard DIN 4102 (Part 1,1977) loam (earth building material), even with some straw content, is "not combustible" if the density is not less than 1700 kg/m^3. Cob's density varies from 1400 to 2000 kg/m^3. For an average density of 1700 .

THERMAL PROPERTIES OF COB *references 10, & 11*

Including the surface coefficients, a 2 ft thick cob wall has an R value of 4.3.(in Imperial units).

Australian research into the thermal performance of earth buildings including Cob. A technical exploration of thermal resistance of adobe, mud brick, and cob walls covering conductivity, density, humidity, cyclic performance of walls, thermal comfort, whole building performance and an analysis of whole building heat flow performance for both summer and winter conditions. The paper's conclusions: Cob has poor thermal performance. This can be compensated with by good passive thermal design: 18" or thicker exterior walls; internal mass elements; light exterior wall finish; insulation of walls, roof and floor. While not included in the Australian research, solar gain is also an important component of passive thermal design and worthy of being included the architecture of cob buildings.

COB AND THERMAL COMFORT *reference 5*

As mentioned in Sustainability, cob has qualities which creates a positive indoor environment: regulating humidity which influences perceived thermal comfort; binding airborne toxins and odors which reduces the need for ventilation; airtightness which retains interior heat; and thermal storage of solar gain or interior heating.

CONCLUSION

Cob is a valuable and highly sustainable system of building. The economy and environment of North America will benefit from its use. A growing segment of the North American population desires to build with cob, but the current regulatory situation is a barrier to cob. The building codes lack of understanding and acceptance of cob is preventing the widespread realization of its benefits. The solution to ending this barrier can be found in the creation of cob standards and a cob specific building code. It is for this purpose that the Cob Technical White Paper research is being conducted. Both the author's prior cob experience and this current research show that while there is much existing information on cob, it is incomplete, scattered, and disconnected. The existing information on cob needs to be tied together, and where a lack of information is found, research needs to be done to fill the gaps. A comprehensive coordinated program of cob specific research needs to be conducted with the goal of creating a Cob Building Code designed to set cob free and allow it's legal construction throughout North America. This is a major project which needs to be supported by the earth building community.

This paper is presented by the Cob Research Institute (CRI), a non-profit 501(c)3 organization dedicated to the realization of this goal. Please contribute to CRI and support legal cob ! www.cobcode.org

As the author, I am not an academic & this is written from the standpoint of a cob practitioner and architect. The academic organization and clarity presented is the work of Lola Ben-Alon.

I hope you this paper is informative and useful, Thank you - john fordice

References: A list of the research resources reviewed as of the publishing of this paper.

Conference proceedings limits do not allow a comprehensive discussion of these resources in this paper. They will be addressed fully in the future publication of the **CRI Cob Technical White Paper.** Researchers interested in accessing these materials can contact the author. jfordice@cobcode.org

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