Regulatory Challenges for Building with Rammed Earth in Canada

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**Abstract.** Since 2005, the model national building code of Canada has contained an alternative solution application protocol, allowing the proposal of novel materials and designs to meet the objective and functional statements that express the full intent of the legislation. Each province or territory adopts the model code with additions, deletions and amendments. The code is enforced at a municipal level, augmented by region specific by-laws. The challenge for designers and builders is to put together permit submittal packages that satisfy plan examiners who are not likely to be familiar with the materials or methods of construction being proposed. In the case of more densely populated jurisdictions, the plan examiners may themselves be professional engineers practicing under a code of ethics that demands a high degree of due diligence. Demonstration of equivalence to an existing design standard for a similar material is often required by code officials – in the case of rammed earth, conformance to accepted concrete or masonry design methods. Materials testing to confirm assumed design strength before permit granting is required, along with testing during construction to assure quality in the actual building. The challenge for regulatory bodies is to provide fair and timely review of submissions and to guide proponents along a code and by-law compliant path without actively joining the design team. A major factor limiting the involvement of authorities having jurisdiction is the question of liability in cases where problems arise. All of these challenges can also be expressed as opportunities for collaboration, education and risk reduction between design professionals, builders and regulatory officials. This paper discusses these challenges and opportunities using actual practice examples where appropriate. The authors also propose recommendations with regards to the design-approval process.

**Introduction**

Authorities having jurisdiction in Canada are currently administering in the second code cycle since the introduction of an objective-based national model code. The first National Building Code of Canada (NBCC) to adopt an objective-based format was issued in 2005. The Canadian Commission on Building and Fire Codes issues an updated version of the major codes (Building, Fire, Plumbing & Electrical) every 5 or so years. The current national model building code is the 2010 edition, with a 2015 edition on pace to be issued late in 2015 or early 2016. [2]

The move to an objective-based code involved the addition of alternative regulatory paths to permit acceptable equivalent solutions to augment the listing of prescriptive solutions for well known building materials and assemblies. By defining the goals of the code via cross-referenced objective and functional statements, the objective-based format attempts to give designers and code officials methods to evaluate a potential design for code conformance apart from a ‘cook-book’ approach. Although the alternative solutions proposal protocol was first introduced in 2005, differences in the way that each province and territory adopts the model code into their legislation, compounded with differences in the way any given municipality enforces their regional code and/or modifies it via local by-laws, has left today's designers and project proponents with an inconsistent set of conditions to deal with when applying for a permit to build.
Before the adoption of the objective-based model code, non-conforming materials and designs were permitted on a project-by-project basis, either via the building official’s discretion, as part of some type of approved research program, or because of exceptional circumstances. An example of the building official’s discretion is given in the first case study below. An approved research program is most often a case where a municipality and an academic or research institution cooperate to demonstrate a novel building technique that is funded publicly. Exceptional circumstances are really an extreme case of this; for instance, an Olympic village or World’s Fair site. It is not the purpose of this paper to deal with projects of that magnitude per se, rather the example is given because those projects are also designed, permitted, insured and funded – a similar process, but at a scale much higher than small to medium scale residential builds.

Both before and after the advent of the objective-based code model, a key element to winning the building official’s approval directly or via a research program is the establishment of material qualities that can be measured and shown to be consistent with the design methodology adopted by the engineer or architect. This is a primary challenge for the designer; choosing an accepted design methodology developed for a similar, yet different, material and then developing a test method to prove that the different material behaves sufficiently like the accepted one to justify the analysis and final design. Two examples are given in the case studies, one following the Canadian concrete design manual and the other the Canadian masonry design manual. National engineering design standards and their accompanying manuals, guides and commentaries are published by the Canadian Standards Association (CSA).

The Canadian Construction Materials Centre (CCMC) is responsible for evaluation and national certification of innovative building materials, products and systems. Conventionally, a material or product attains CCMC certification in order to be widely accepted by designers, regulators and builders. All CCMC certifications are referenced in the NBCC by default, allowing relatively easy specification and acceptance. At some point in the future, the material or product may be cited directly in the body of the building code itself. Polystyrene Insulated Concrete Forms (ICFs) are an example of a product, or building system, that has gone from CCMC evaluation to outright specification in the national code within the past 20 years. Structural Insulated Panels (SIPs), the majority of which are made up of OSB sheathing adhered on either side of a polystyrene core, are an example of a product/system that has not succeeded in being included in the national code despite some individual manufacturer’s attaining CCMC certification. In both cases, the product, or building system, is a combination of previously known materials in a particular method. However, while ICF proponents have been very successful in getting their product explicitly specified in the NBCC, SIP proponents have not had the same success.

The variability in aggregate content, mix recipe and method inherent in working with natural or pre-industrial materials and techniques such as stabilizedrammed earth (SRE) effectively precludes evaluation by a body like the CCMC. It should also be noted that the evaluation process is lengthy and expensive, and to date there have not been any proponents of earthen construction in Canada willing to attempt it.

This leads to a situation in which each project is evaluated on it’s own merits, and raises further challenges. Before the issuing of a permit, inspection criteria must be determined along with a quality control and materials testing program to be carried out during construction. A requirement for any project varying from common construction techniques or materials is a commitment to general reviews by the lead structural design professionals. This establishes the party or parties responsible for inspections and site reviews, and generally includes a document clearly stating the agreed upon inspection schedule, notable milestones and substantial completion criteria. Two different pre-construction testing programs and two different construction phase inspection protocols are given in the case studies.

**Case Studies**

**Extra-urban residence – Huntsville, Ontario.** The Allen residence, located just outside of the
town of Huntsville, in the Muskoka region of Ontario, was completed in the fall of 2012. It was the first SRE single-family dwelling to apply for a building permit in the region. The pre-construction materials testing program for this project was initiated in the spring of 2010.

The town of Huntsville has a Development Services branch, which includes their Building and Planning Departments, along with By-Law enforcement and Sustainability. As of 2013, the Building Department did not employ any registered professional engineers for plan examination or inspection. Plan examiners and inspectors have previous experience in construction, hold journeymen certification in one or more of the building trades (plumbing, electrical, mechanical or carpentry) or are either civil or architectural technicians.

The design methodology for the engineering of the SRE walls on the Allen residence was a hybrid of the Canadian Concrete Design standard CSA A23.3 [5] and various techniques and analysis tools taken from the international literature. Of primary concern was the effect of freeze-thaw cycles on exposed SRE walls in a Canadian climate. Pre-construction testing included evaluating different grain size distributions in the source soil mix, varying Portland cement content, the addition of a silicon emulsion admixture for permeability reduction (Plasti-cure by Tech Dry), and oxides for colour control. The structural design was controlled in large part by the compressive strength of the test samples. 150mm diameter x 300mm tall test cylinders were tested at 28 and 56 day curing times. The durability of the different mixes was tested by exposing block style samples to the environment and by simulating excessive freeze-thaw cycles during the winter months.

For durability, a minimum Portland cement content of 5% by weight, plus the manufacturer’s recommended dosage of admixture to reduce permeability was determined to be adequate. For structural stability, a minimum of 7.5% Portland cement by weight was determined to be necessary to achieve a 15 MPa design compressive strength. The testing program was summarized in a simple document and presented to the building officials in Huntsville along with the completed drawings set at the time of permit application. The building official requested an in-person meeting with the structural engineer in order to discuss the material and building technique, and was satisfied within 15 minutes; provided that the engineer sign a commitment to general reviews document to explicitly take on responsibility for inspecting the SRE walls and assume full liability for their performance.

Follow-up testing involving samples taken during construction was requested, but occupancy was not denied before the test results were submitted after construction was completed.

Urban residence – Ottawa, Ontario. The Smyth-Allcott residence is a two storey single family dwelling currently under construction just south of Ottawa, Ontario. The building has single storey stabilized rammed earth walls with light wood frame second storey walls above. The conceptual design was taken to the city of Ottawa’s building department for an initial consultation by the client and architect in April of 2012. At that point in time, a zoning official looked over the proposed design and did not see any outstanding issues that would prevent or delay a building permit being issued.

Following a similar pre-construction testing program to the one employed for the Allen residence, the design was completed over the winter and spring of 2012/13. The city of Ottawa is in a seismically active zone, and the appropriate lateral load capacity of the structural walls is required to be demonstrated in any engineering design submitted for permit.

The city of Ottawa has a Planning and Growth Management Department, employing several registered professional engineers and architects in the Building Code Services division. In the case of the Smyth-Allcott permit application, a technician in the residential plan examination division received the plans but passed them up to an engineer in the commercial plan review division. The technician did not feel qualified to review the plans, as the structure included materials and techniques outside of part 9, the prescriptive residential building section of the Ontario Building Code (OBC).

The structural engineer reviewing the set of plans and calculations was not familiar with earthen construction methods, nor with SRE as a material that could be designed using engineering principles. As a result, the engineer requested evidence via testing done in a Canadian context to
prove that stabilized rammed earth could reliably be designed in general accordance with CSA A23.3. Notwithstanding the lack of published research on stabilized rammed earth from Canada, two larger concerns were raised regarding the use of the concrete design standard for this different material. First, the minimum compressive strength for reinforced concrete is currently set at 25 MPa in the CSA design standard. Second, the CSA A23.1 and A23.2 standards [3, 4] set limits to the quantity of particles of less than 80 µm diameter present in a given sample of aggregate. The inability of SRE to meet these two qualities effectively ruled out the use of the concrete design standard for engineering analysis in this case.

Supporting documents submitted with the initial permit application included the New Zealand Engineering Design of Earth Buildings (NZS 4297:1998), which is written taking into account both masonry and concrete design methodologies for reinforced and un-reinforced assemblies alike. Reference to this standard prompted a re-design carried out in general accordance with the CSA S304.1 standard, Design of Masonry Structures [6]. The minimum compressive strength for reinforced masonry under seismic loading in CSA S304.1 is 15 MPa, and the standard contains no minimum aggregate size criteria, as masonry containing clay - both fired and chemically stabilized - are permitted.

The primary change to the engineering analysis resulting from the shift to a masonry-based standard from a concrete one was the increased importance in slenderness ratio as opposed to reinforcement in driving the final design.

In terms of the permit application process, the fastest path forward was determined to be an alternative solution application asserting the equivalence of the reinforced stabilized rammed earth wall to a reinforced masonry wall. This necessitated a revision of the materials testing protocol, as the CSA S304.1 standard does not reference concrete testing methods or include methods to utilize data from cylinder compression test results. Instead of cylindrical samples, rectangular prisms were required. The change in sample size and geometry proved to be a significant hurdle, but one that was ultimately overcome by cooperation between the SRE builder, a local community college in Ottawa and a commercial testing lab in Brampton.

Conclusions & Recommendations

Building with pre-industrial materials and labour intensive methods such as rammed earth or adobe blocks presents a challenge for both designers and regulators in a post-industrial, liability conscious environment. However, even industrial building materials are not instantly accepted by the current regulatory community, as the SIP manufacturing industry in Canada will tell you. The evolution of objective based codes in Canada provides an opportunity for non-conventional materials and methods to achieve code compliance on a project by project basis.

It is common to encounter different interpretations of building code requirements between different jurisdictions. It is also common to find that a jurisdiction with a larger population will have more rigorous plan examination and inspection requirements than a neighbouring jurisdiction with a smaller population. In large part, this is due to higher staffing capacity and experience with a broader variety of projects in the more populous region. However, the resulting inconsistency in the application and enforcement of federal and provincial codes at the municipal level effectively creates separate classes of construction regulation where no such separation is intended, or even allowed.

Our recommendation is for regulators to set a minimum level of adjudication necessary for an alternative solution proposal to be considered. This may involve third party professionals in some jurisdictions, but this is not unprecedented for plan examinations or inspections that are outside the expertise of the staff in any given building department.

Correspondingly, designers must educate themselves about what regulators need to see in order to move a permit forward when an unfamiliar material or building technique is being proposed. The challenge lies in working together without blurring lines of liability and client responsibility. At the same time, the opportunity exists to work together to create clear and consistent design and administrative guidelines that lead to a better built environment.
References


