LEGAL ADOBE IN CALIFORNIA: A PATHWAY FOR BUILDING PERMITS

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Abstract

Once a popular construction material, adobe new home construction in California has become nearly non-existent. Contrary to popular belief, this is less attributable to appropriately-designed adobe's ability to perform in earthquakes than the difficulty of navigating the California Building Code in the absence of an industry to advocate for better standards. Despite these challenges, construction and permitting of load bearing adobe structures is possible in California. This case study will outline the approach used to achieve structural and energy code compliance and permit issuance on a single family home in Pioneertown, California as well as offer suggestions for research and code development work needed to enable simpler compliance paths.

Project Background

Loescher Meachem Architects has long held the goal of proving that adobe could be legally used for single family residential construction in California. No legally constructed adobe residence had been built in California since the completion of the Love Adobe, permitted circa 2001, and in the intervening two decades the regulatory bar had become even higher. Our intention has not been to displace frame construction as the dominant residential construction material in California - there are good reasons to utilize wood construction in a highly seismic region and in the context of climate change. But wood construction is highly susceptible to wildfires, is challenging for owner-builders, and in many regions dimensional lumber is not available or has to be shipped enormous distances. Permitting an adobe residence in California was based on ambitions that extended beyond the State:

- Perceptions of adobe's suitability (or unsuitability) for use in seismic regions has largely been based on the performance of traditional structures which have not had the benefit of modern engineering. Demonstrating that adobe can be permitted in California would go some way to proving that adobe and other earthen materials are not universally inappropriate for seismic areas.

- The effort and process of permitting an adobe structure in California would expose issues of building regulation and interpretation that were not otherwise obvious, and could inform improvement of building codes at the national level.

In mid-2020, LMA met Rex Edhlund, a mid-career creative director who had recently relocated from San Diego to Pioneertown, California. Edhlund had become aware of LMA's work in adobe and earthen construction through the classes and workshops that Ben Loescher conducts through adobeisnotsoftware and approached Ben about the potential for making adobes and constructing his own home. The initial conversation included the cautions built into any such undertaking that it was unlikely to be cost-effective unless Rex provided the bulk of the labor; it would certainly take longer than the permitting and construction of a conventional home, and it wasn't entirely clear if San Bernardino County would even ultimately approve the plans. Rather than being dissuaded, Rex took it as a challenge and became determined to use his new home as a test case to prove that an adobe residence could be legally built in a highly seismic area within California's complex system of building regulation. LMA quickly partnered with Berkeley-based Verdant Structural Engineers whose Principal Anthony Dente was the principal author of the structural sections of the Cob Code now included in the International Residential Code as Appendix AU.

History and present of adobe regulation in California

While a full history of the regulation of adobe in California is beyond the scope of this paper, it is sufficient to say that where adobe was for much of the 20th century a common construction material in California, the lack of advocacy from a mature adobe industry as well as building and energy codes authored without earthen materials in mind have made building with adobe more and more difficult. Like other jurisdictions in California, San Bernardino County relies on code standards published at the state level and adopted locally:

- Building Code provisions are based upon edits and modifications of the International Building Code (IBC) and known as the California Building Code (CBC). Although the California Residential Code (CRC) is usually used for single family residential construction in the state, no adobe provisions exist within the CRC and it is permissible to use the more complex and stringent CBC provisions (which include Adobe in Chapter 21) for residential construction. Although that would seem to provide an obvious path to inform structural design, the text is imperfect. Section 2109 is entitled "Empirical Design of Adobe Masonry", however it limits the design methodology to regions with low seismic and wind forces; further, the section refers the designer to a reference standard known as TMS-402 in which the words "adobe" or "unfired clay masonry" do not appear. This creates a situation that challenges both the designer and the plan reviewer as there are no clear and unambiguous standards to design or review against.

- Energy performance is measured against the California Energy Code, commonly and somewhat erroneously known as "Title 24". Title 24 is entirely unique to California and more stringent than the International Energy Conservation Code used in most of the rest of the United States. In most cases the text and application of Title 24 is straightforward; we would however find that there are significant flaws in commercial software used to generate the documents necessary to provide compliance.

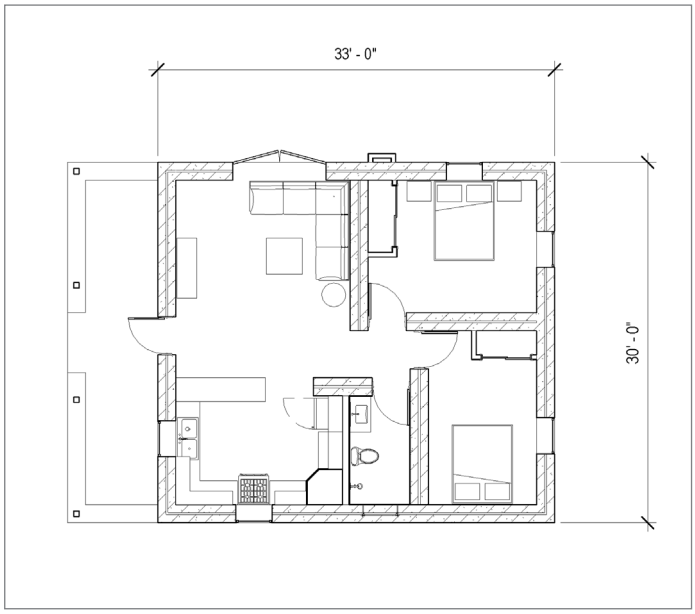

Figure 1. Floor plan.

The Proposed Building

Rex desired a relatively compact building with two bedrooms and one bath that could act as an obvious visual advertisement for adobe construction (Figure 1). To achieve this, we settled on a construction system that would utilize asphalt emulsion stabilized adobe which could remain exposed without requiring stucco, plaster or other finishes which would obscure the structural adobe. It also meant that any required insulation would need to be within the wall system rather than applied to the exterior as is more common in New Mexico. The reinforcing system would be based on a concept (Figure 2) that Fred Webster introduced to LMA on an earlier project and tested for constructibility in a small "proof of concept" structure built for LMA by Cornelia Theimer and Kurt Gardella in Pioneertown in 2018: vertical reinforcing would be accomplished using "pre-stressed" or "post-tensioned" threaded rods within a 2" reinforcing and insulation chase captured between two wythes of 8" wide adobes. The chase would be packed with light straw clay to provide insulation necessary to pass the energy code requirements, threaded rods would run through PVC pipes to prevent any coupling of the threaded rods to the surrounding earth/straw matrix. Unlike reinforced concrete where rebar and concrete bond and combine their relatively high respective compressive and tensile properties, rebar and earthen materials bond very poorly, yielding no such beneficial composite effects.

The design of a California compliant design faced two significant hurdles: demonstrating compliance with the structural aspects of the California Building Code which were not authored with adobe in mind, and proving that an adobe wall system could meet the thermal resistance minimums of an energy code.

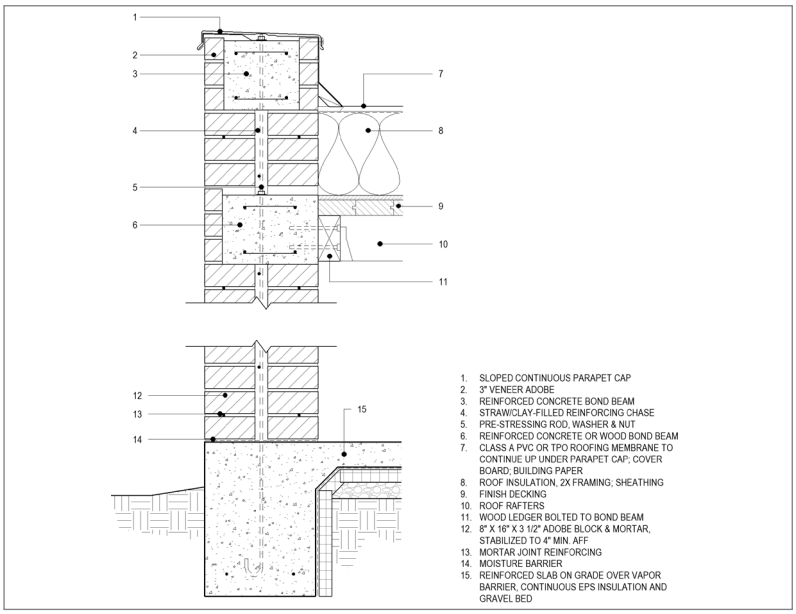

Figure 2. Typical Wall Section.

Structural Design

The primary structural hurdle for adobe construction, particularly in high seismic regions is the lack of building code incorporated or associated accepted design parameters. Numerous structural research efforts have been conducted on adobe, many concerning existing or historic adobe construction through entities like the Getty Institute involving engineers such as Fred Webster, SE, though there are a number of conventional researchers focused on new construction. Non-codified or building types that aren't fully codified, which are categorized as Alternative Building Materials under the IBC or CBC Section 104.11 should be expected to be structized during the plan check process. For every building in this category that Verdant Structural Engineers (VSE) has pursued a design for, with a client who was dedicated to see it through, we have, with compromise, acquired a permit for the system. The Edhlund Home project is no exception to that.

This project had 3 rounds of plan check, though the third was mostly a formality. This process required 3 separate primary structural design/calculation strategies. It also possibly crossed the line of a building department's jurisdictional reach to refuse to review an Alternative Material submittal as explained below.

Original Design:

The structural wall system consists of 2 layers of adobe block with joint, "ladder" type, mortar bed horizontal reinforcement and vertical bar reinforcement contained in an internal insulation layer between the adobe spanning from the concrete foundation to the concrete bond beam.

As with all materials that are not codified or fully codified, Verdant Structural Engineers originally approached this project with the three step approach of 1) generating allowable design values based on available research and factors of safety based on industry norms concerning material, volume of testing, and scale of testing. For small scale testing this can be as high as 10, while for full scale wall testing will range from 2-5. Then 2) we used material quantities to conduct analysis based on engineering fundamentals and 3) we ran analysis based on the most relevant existing codes on the subject globally. IBC Section 2109 was considered in this, though the New Zealand Earthen Standards are the most developed performance or engineered code on the subject. In the first and second design approach for this project, we used conservative seismic Response Modification Factor (R-Factor) of 2.75. No existing adobe code contains a required R-factor for the system used on this project. R-Factor is the variable that correlates the amount of building weight that is required to be converted to seismic weight with the ductility or energy dissipation of a system. When abundant testing is unavailable, it is difficult and likely inappropriate to assume favorable R-factors. R-factors appear in the denominator of the seismic base shear equation and therefore a higher value means your building demand load will be less. For comparison, wood stud walls with plywood sheathing have an R-Factor of 6.5. ASCE 7-16 does cite R-Factors for Plain Masonry Shear Walls and Reinforced Masonry Shear Walls, though neither of these values are directly appropriate for our system as the reinforced values were not derived with this type of system in mind, and the plain values are not appropriate because they walls are reinforced. Though they do serve as a quality basis of judgment for comparison.

1st Plan Check Comments:

In the first plan check response for the building department of San Bernardino County they stated “Design of structure requires additional reports justifying load resisting elements and material strengths of Adobe, masonry construction. Please obtain specific testing reports through ICC, City of LA, etc. Structural review will proceed once additional reports are provided.” My interpretation of this statement is that they are requiring an International Code Council (ICC) - Evaluation Service Report (ICC-ESR) or similar document supplied by the County before they will review the structural calculations and supporting documents. An ICC-ESR is a report that can be produced by a branch of the ICC that offers a service, primarily for proprietary products, who, by nature, cannot be included in the building code. The ICC typically requires approximately $10,000 to initiate the review and the full process and cost much more. It is also not meant to support non-proprietary building systems because if those systems have enough information to gain an ICC-ESR, they should be proposed for adoption into the ICC codes or I-Codes which are the model codes for most of the USA. From my interpretation, and backed by a confirmation from Martin Hammer, architect who has authored numerous ICC code appendices on natural building materials and more, it is not valid for a building department to reject a design submitted under CBC 104.11 simply because it does not have an ICC-ESR. Under the alternative section of the IBC and CBC is section 104.11.1, Research reports, which states, “Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from approved sources.” The word “approved” means approved by the building official. So it gives the building official a lot of discretion, and their policy may boil down to an ICC-ESR. However, more importantly IBC or CBC section 104.11 begins with, “The provisions of this code are not intended to prevent the installation of any material or to prohibit any

design or method of construction not specifically prescribed by this code," Any mandatory requirement for an ICC-ESR runs counter to the letter, intent, and spirit of 104.11 in my and Martin's opinion.

Most importantly, this project had myself (Anthony) and VSE as an engineer, and my co-author, Ben Loescher, as an architect. Collectively we have submitted many permit applications for alternative materials and have authored and defended multiple code sections and appendices in the I-codes. It is easy to assume that a project without this type of expertise could easily be intimidated away from using adobe after this 1st Plan Check response, an outcome would be unfortunate and likely inappropriate.

Second Design Approach:

Following a call and email exchange with the building department, they suggested we resubmit, identifying the primary and sole basis of design being IBC or CBC chapter 2109, which is for the empirical design of adobe construction. We had not gone this route originally because IBC or CBC chapter 2109 is not permitted in Seismic Design Category (SDC) D, which is the SDC in most of California, and was the SDC for this site. Though it was understood they were making an exception and were relaxing that requirement given the calculations were justifiable.

Plan Check Comment 2:

It is still unknown what the intention of the San Bernardino County Building Department was in suggesting we resubmit solely under IBC or CBC chapter 2109. They sent the second submittal to an outside plan check company Interwest, where Bill Rogers, SE oversaw the review. A fun fact is that Bill Rogers was also the hired plan check engineer for my (Anthony) and VSE's first California cob building permit in Berkeley California. The two projects were approximately 500 miles and nearly 10 years apart. Bill and Interwest responded confirming the stricture of IBC or CBC chapter 2109 in SDC D though suggested the option of, "It may be possible to justify the use of adobe as a special reinforced prestressed masonry walls per TMS 402, Chapter 10 and Section 7.3.2.12 under an alternate means and methods request, but a detailed evaluation by the EOR is necessary."

Third Design Approach:

The project was redesigned using the code requirements for prestressed masonry walls. One positive that resulted from this change was, due to the more strict design parameters of this section, there was a clear justification for using a more favorable R-factor, associated with prestressed masonry walls of R=4.5.

Prestressing the tendons does not increase the strength of the wall. The purpose of prestressing is to apply a compressive stress on the wall to counteract the max tensile (uplift) stress from applied loads. When the max uplift force occurs, the wall's net compression will be 0. This results in the wall never being in a tensile state.

This design transition had a number of drawbacks including the following. It complicated the installation and inspection process which will require a mason skilled in prestressed masonry and a qualified inspector with experience in prestressed inspections. Also, the synthetic geogrid, of the sort represented in the New Zealand Earthen Standard, was not an acceptable horizontal reinforcing.

Plan Check Comment 3:

This final round revolved around differing interpretations regarding how using the prestressed masonry code as an analog for adobe construction should be employed.

The permit was issued following this submission.

Thermal Performance

Most residential designers in California rely on outside consultants to perform the calculations and produce the outputs required to demonstrate energy code compliance during plan check. These services typically cost a few hundred dollars and are performed by simply selecting from among standard wall and systems options built into various commercially available software packages (such as EnergyPro and Right-Energy Title 24) with little judgment exercised by the consultant. Unfortunately, no earthen wall systems are included within these packages. In our case, once the consultant was engaged and started the input process, they quickly came back to us saying that it was not possible to model any wall system not built into the software and that there was no alternative method available. This was contrary to our experience using performance based compliance on more complex commercial projects, but a call to the California Energy Commission seemed to confirm what we had heard from the consultant.

Fortunately, Martin Hammer, a California Architect with a great deal of experience with strawbale construction introduced us to Beyond Efficiency, an energy consultant familiar with compliance for unconventional building systems.

Principal Dan Johnson's approach was remarkably straightforward. Beyond Efficiency first calculated steady state U/R for the entire assembly in a spreadsheet using accepted values for air films, adobe bricks, and light straw clay insulation, arriving at a total assembly with a calculated U value of 0.094 which surpassed the Title 24 performance minimum of 0.125. Then, using open-source software called CBECC-RES sanctioned by the California Energy Commission, Beyond Efficiency created an assembly with an equivalent U/R, which in our case was a 16" Adobe with R 3.6 rigid insulation until the model and spreadsheet values match. This was still less than the U value prescriptively required for framed exterior walls in our climate zone, but this was offset by recognition that mass walls tendency to absorb and release heat, and the project's use of appliances and roof construction which were significantly higher than those ordinarily required. This "trade-off" approach where relatively low performance of some systems are offset by higher performance of others is acceptable in California.

Conclusion & Areas of Improvement

Having received the necessary permits, Rex is currently fabricating blocks for his home with construction expected to complete sometime in 2024. In the meantime, we have had time to reflect on what was learned during the design and permitting process, as well as consider next steps that might benefit future projects as well as the adobe community more broadly.

Conclusion 1 - Seismic Performance

Better quantification of the seismic performance of adobe is needed. Continued testing is needed on all proposed reinforcing systems being designed into adobe walls. Many rounds of testing is required to propose variables like new material R-Factors to the ICC for code inclusion. The newly enforced FEMA p695 peer review process would likely be a required presence in the testing design and execution.

Conclusion 2 - Energy Modeling

The software used to demonstrate energy compliance is extremely deficient when it comes to accurating predicting the performance of earthen mass walls. While a long-term goal of the adobe industry has been broader adoption of a system similar to New Mexico where mass walls are given effective R-values based on climate zone, wall orientation, finish color and assembly detail, a first step is even more necessary. The entire building community must demand that any software package recognized by review jurisdictions needs to include every material recognized by the IRC and IBC.

Conclusion 3 - Code Reform

The International Building Code and TMS 402 must be updated to include earthen building systems and provide design methodologies appropriate for their use. In September of 2022, the International Code Council will undertake final rulemaking which could remove adobe from the IBC. While this outcome may yet be prevented, regardless of the result the earthen building community needs to shift its focus from defending current code standards to creating and expanding rationally derived and appropriately conservative new standards that evaluate adobe to the same criteria used for other “conventional” building systems.

If you are a professor or graduate student, have access to a lab or funding, have technical grant writing experience, or anything that could assist future adobe testing and code advancements, please reach out to the authors of this paper or The Earthbuilders Guild (TEG). If you have experienced a building department denial to review an alternative material of any time, please let us know the specifics of your experience.

Acknowledgements

Special thanks and credit to Anthony Dente's coworker Jill Cleveland Joda at Verdant Structural Engineers who put a lot of hours into engineering this building, Martin Hammer whose resourcefulness and tireless advocacy for unconventional building systems continues to inspire LMA's work, Dan Johnson and Beyond Efficiency without whom this project might never have been permitted.

Anthony Dente *is Principal at Verdant Structural Engineers and Vice President of the Cob Research Institute. He was the lead engineer for the Cob and Hemp-Lime (Hempcrete) IRC appendices. Anthony has extensive natural building testing and permitting experience. He's the project lead for an EPA SBIR grant for prefabricated straw wall panels. Anthony's work was recently recognized by the Constellation Prize.*

Ben Loescher *is a founding Principal at Loescher Meachem Architects where his work focuses around reuse of existing buildings, high performance workplace design for the film, television and media industries, and innovation in earthen construction. Loescher provides education for earthen building through adobeisnotsoftware, is currently Chair of the Earthbuilders' Guild, the U.S. trade association for earthen construction and a board member for Adobe in Action, a New Mexico based non-profit focused on assisting individuals in creating affordable earthen housing.*