Since we covered some of the conversation of natural building before, I'd like to move more into the materials and techniques and methods that are used. And last time we touched on straw-bale and earth plaster in some detail, but I was wondering what your thoughts are for things like straw-clay slip, rammed earth, earthbag, or even something like the earthship style of construction.

BT: Well, I'm reluctant to comment too much on them, fundamentally, because I haven't worked with them. And, you know, it seems to me a little disingenuous to start dishing out comments on things that you don't have physical experience with. I place a huge amount of emphasis that anybody who's going to design with any material, they should get body knowledge of what the material feels like, and not just be abstract about its qualities and so on.

So, with that as a prelude, however, I'm always willing to hold forth on things. And I get, what I can tell you is why I haven't been pursuing some of these things. Some of them are particular to the environment here in California, but others of them—now there, are some general principles that have actually been responsible for me not pursuing some of these. The most important one being that there's something of a misconception going around these days that mass walls are always a good idea, shall we say. You know, and when I was learning about passive solar design in the seventies, we approached it that way. It was sort of like some mass was good, more is better, and therefore, you know, rammed earth wall is a great thing 'cause it's soaking up tons and tons of heat. And, this is all good.

What we learned is that on a daily cycle, only about two inches of the surface of your walls will actually be cycling through the temperature swing. So a twelve-inch thick mass wall might be of some use to you for four or five days of unseasonably cold weather, or something. But in point of fact, you can get practical, you know, for all practical purposes, I'll put it that way: two layers of drywall, to be really non-natural about it, or an extra-thick coat of plaster on the inside of your house will give you all the thermal mass you need for most of the time. And so, we found that you don't need mass nearly as much as you just need insulation on your building.

And the fact of the matter is that all the ones that you mentioned—oh, with the possible exception of light straw-clay, light straw-clay is fairly good insulation, but rammed earth and earthbags and earthships are all mass walls. And that kind of mass just isn't going to serve you very much and in point of fact, here in California, it works directly against you because these are very massive walls and they're not terribly strong materials. Even the rammed earth, I mean once you add five percent **(5:00)** cement to rammed earth it's efficient to make it strong enough to resist earthquakes without cracking and behaving in a brittle manner. You basically added as much cement to the wall as you would if you were casting it in concrete. You basically produced a weak version of a concrete wall.

And so, I spend most of my time just telling people who are really interested in natural building, first and foremost, make sure you've got a well-insulated envelope. Because that comes first, and then, adding some mass to it helps even out your temperature swing. *Provided*—and this is the important thing—provided you are in a climate where the daily temperature swing gets above and below our comfort temperatures, you know, between sixty-five and seventy-five degrees. That's why earthships did so well in New Mexico and the Southwest, is because even in the winter time, you get a lot of good, strong sun during the daytime which can really pump a lot of heat into your envelope and then it cools way, way down at night, as it usually does in a desert climate.

And so, adobe before it and rammed earth and these other mass techniques work quite well down in the Southwest because, as a desert, you get a large temperature swing and a mass wall tends to even it out. But the fact of the matter is, if you do a well-insulated envelope, you get much the same effect. And, in the process, you don't need the daily input of the solar radiation. You don't have to turn your building—in design terms—into what looks like a solar cooker, the way that we did in the seventies, you know, with huge amount of glass on the south wall to pump lots and lots of heat in when the sun is shining. And then you've got the issue of, oh, okay, well what about when the sun goes down and all that glass is *losing* radiation out to the outside, and okay, do you do blankets over the wall, and so on and so forth. And always become quite complex.

What we've learned in the intervening years is, create a super-insulated envelope, and then you need very little in the way of south-facing glazing to provide some additional solar input for passive solar heating. And so, you know, we used to be kind of, we had this simple dumb formula about things and now things are a little more sophisticated. But actually, in point of fact, make it a little simpler. Because a well-insulated envelope is most of what you need.

And, you know, to be fair, we are now going through the process of learning the ramifications of a well-insulated envelope. Because it used to be that our envelopes were so leaky that all the air moving out of a building—you know, normally you have in the wintertime which is when we concern ourselves with these things—all the air moving out of the building tended to dry out any condensation that might form in the walls. There was just so much heat moving through the walls that you didn't have to worry about that.

Now that we're adding extra insulation to the building, we're getting into situations where moist air moving from the inside to the outside can actually condense inside the walls and will create condensation issues, and now we have to learn how to seal up the building as well as super-insulate the building and we're finding out that there are good places to put insulation and bad places to put insulation depending upon the particulars of your climate. So, it gets a little more complex if you simply add more insulation to your building, but the fact of the matter is, we're getting better buildings as a result.

And that's one of the reasons why I'm still sold on straw-bale construction is that it's a super-insulated envelope, so it starts with the right thing, but you, it's very easy to add the mass on the interior. I mean, you're always adding mass onto the interior of the walls because the straw needs something in the way of a finish and that finish *always* is adding mass so if you just take the time to make the thickness of that interior plaster surface a little thicker than you might have otherwise, you've pretty much optimized your passive solar profile of the building.

So that's my biggest piece of advice for people, is really, you know, I get, for example, you hear all the time in natural building circles about great new ways to do a roof, you know. Various and sundry means by which to span between walls. And my operative question is always, "In an industrial environment, there are thousands of clever ways to span between walls. What are you doing to insulate this device that is spanning between your walls?" And all these fabulous new techniques usually turn out to be shells of one form or another. **(10:00)** You, know, a [unintelligible] shell, a fiberglass shell, and so on and so forth. But it's really the insulation that is crucial, particularly in the roof.

Say you're doing an earthship kind of thing. For an, as an example, you're going to be tempering the thing by partially burying it and putting dirt on the roof and all that good stuff is going to help. But if you're in a situation where you've got long periods of cold weather, the fact of the matter is, all that thermal mass is not keeping the heat inside, it's like a thermal nosebleed and you're just bleeding heat out of that mass because earth is not a great insulator. You need a good amount of insulation up in your roof area because with the way heat rises, the hottest surfaces of your interior environment are up at the ceiling, and so that's where you need the most insulation.

And roof insulation is a tricky thing to do with natural materials. I've made something of a name for myself within the natural building world and especially within the straw-bale world because I've been particularly interested in taking the stawbales up into the roof structure. Either in the form of it simply being up there in the roof, you know, bales with, you know, normal sort of wooden structure. But more importantly, because I've done enough work in places where wood can be a *huge* amount of the construction budget, you head down to New Mexico, that's the case. But in particularly places like Central Asia and so on, where it's really hard to come by wood.

I've done a lot of investigation and built a fair amount using the straw-bales in a, an arched format so the bales don't just stop at the top of the walls, they continue up and over structurally as, as the structure of the building roof. You know, vaulted structures, basically. That was really an outgrowth of this realization that it's all well and good to have natural materials for your walls, but our real frontier now is natural building in your roof. I think I mentioned this in our last conversation, that you see what, ninety-nine percent of the time, you see people default to normal construction methods when it comes time to build your roof, your respective roof. How natural or unnatural or processed or unprocessed their wall system has been.

It's perfectly understandable that when people talk about a cob house or a rammed earth house or a straw-bale house, they're not really talking about the roof and the roof structure, because we derive our sense of the character of our building from the nature of the walls because that's what we experience. But in point of fact, in technical terms, you could make a great case for the fact that it would be far more appropriate to refer to a house by the structure of its roof. Because there are large parts of the world where a house just consists of a roof, just held off the ground on posts because the climate is that benign and/or they want to maximize ventilation. So in a hot, humid climate, roof is what is primary. So, this is something that, you know, there are a few of us within natural building who have been, really got trying to keep our heads focused on is, how do you come up with a natural roof structure that is doing all the right things in terms of keeping the rain and snow off, but even more importantly is super-insulating the roof structure in the way that we like to do with our walls.

So that's the real name of the game right now as far as we're concerned. In the same way that what, twelve years ago I was something of a missionary from straw-bale construction, but straw-bale has done a fine job of disseminating itself out to the world. I'm now something of a missionary for another ancient technique, and what I was saying about roofs is something of a prelude and gives you an idea of why I'm excited about it. There's a technique coming from the—came from the Mediterranean. It's first recorded mentions in the literature date from the 1300s. It's known by a bunch of names, unfortunately, which kind of confuses people. Timbrel vaulting or Catalan vaulting for Catalonia, the northern northeastern part of Spain where it's best known. Or Guastavino vaulting on the East Coast for the Spanish architect who brought it to this country about the turn of the last century. But its most generic name is probably tile vaulting.

It's a really exciting technique because it is so good at roofing spaces so economically. What it consists of, traditionally, was terra-cotta tiles roughly six by twelve inches by an inch thick. **(15:00)** You set up a profile for the roof, usually a vaulted profile but can, it doesn't have to be circular or arched like a Roman arch, it can be a quite flat arch as long as you're designing the structure so that it takes the thrust, you know, the tendency of an arched profile to push the walls out has to be taken care of somehow, either by buttresses or iron ties or something. Anyway, you take these terra-cotta tiles and, using a gypsum mortar—because it sets so fast—you butter the edges of this thing and you can stick it on the tile before it, edge to edge, hold it there for a few seconds, and then when you release it, it'll still there.

And so you build these things out, gluing them edge to edge out about perhaps two feet. Then you switch to a lime or cement mortar and do two additional layers running at a different direction so you never are aligning up their tile edges. You know, if the first one goes out diagonally, you do the next one at a forty-five degree angle and you do the next one at the opposite forty-five degree angle.

Anyway, what you're doing is you're layering up these tiles. And, once you've taken the two additional layers of tiles out to the edge of where you took the first layer, you can start the process over again. So this tile vault can just be built out into space without supports underneath, what we call centering in the trades. Which is what you're normally required to do, is you have to build the entire vault in a wooden falsework, or centering, so that the material can rest on it while the mortar cures. But, tile vaulting doesn't require that. The first layer set in gypsum mortar does the support for the layers that follow.

And this is just amazing stuff, I mean, what you literally get with this stuff is its strength and cohesion is such that for large spans, when they were doing these on the East Coast, the turn of the last century into about the 1930s, they were producing vaults that spanned ninety to 130 feet that were only on the order of four to six inches thick. So they actually had a thickness to span ratio thinner than that of an eggshell. And it's low-tech, and it's labor-intensive, which for the rest of the world besides us is a great thing, because it's employing people in a good way. But most importantly, you're producing roof structures that don't require the use of concrete, or steel, or even wood. Which means it's extremely valuable in places where wood is like gold.

And then what we're hoping to do with projects that we're work—that I've got on the drawing board now—is we'll put up these tile vaults and then insulate over the top of them with straw-bale construction and then put a roof over the top of that. So this is sort of the new frontier in natural building and so I spent a lot of time making sure that people know about this technique because this really could use some dissemination. I'm always telling people that the real work for us here in this country is to operate as a research lab to investigate and refine natural building techniques so that they can be used in places in the world that don't have access to the thousands and thousands of building techniques, whether industrialized or natural. You know, what we really are doing is, is vetting the techniques that the rest of the world can use out of necessity, where we use them out of choice. And I'm really excited about tile vaulting in this regard.

It does have a caveat, however, that being as thin as it is, it's a brittle technique. So, we're spending some time now researching ways in which could give it a little more ductility so it's not as liable to crack in a seismic event as it is right now. So we need some more work done on that regard. But in the meantime, areas that aren't seismically active can immediately start taking advantage of tile vaulting. And it already is being done; there have been several really exciting demonstration projects in rural Africa using tile vaulting where they're not using terra-cotta tiles but soil cement tiles that they press with a hand press on-site so they'll produce their own tiles and use them on the same site.

So again, making—what's the word I'm looking for—keeping the process labor-intensive, while it's a bad thing in this country it's actually a good thing for most of the rest of the world. So long as it's not too labor-intensive.

One of the questions I was going to follow up with is whether or not one of these (20:00) **Catalan vaults could be load-bearing. But then I found a picture**

of a demonstration done—I, it looks like it was done at MIT—and, they built one over a weekend and it looks like they have one, two, three, four, five, six…eight people standing on top of, probably a five-by-five.

BT: Yeah. This is what architecture students love to do, is build a little vault and then pile all their friends on it. But yes, there was a project in Ethiopia where they built a little model house. And it was a two-story house and so the second floor is a Catalan vault with fill over the top of it. And yes, it's very possible to do and actually very practical to do because the arches which you can use in Catalan vaulting are so flat. You're not taking up a lot of space with a high arch; like a Roman arch you can keep the arch pretty flat, which makes it a more practical technique for multi-story buildings.

And then the arch works because as the weight is put on the top of it, it pushes down into the side supports?

BT: That's correct. The flatter the arch, the more thrust the arch develops. The more it tends to press to the outside. You know, press laterally on the walls. If you can do a very tall arch—actually, you know, if you can use a parabolic profile, or a catenary profile, to be more accurate—you can use a catenary profile, the profile that a chain would take when it's hanging, you can put in an arch that has virtually no thrust on the walls at all. But what that means is it, is that it has to be a very high arch. So it's this trade-off. Either you're doing the flat arch to save space, and you've gotta take care of the thrust. Or you're doing a very tall arch to eliminate thrust, and you've got to incorporate that additional geometric constraint, shall we say, in the design of the building.

So then if it's a flatter arch, the walls need to be able to support any of that outward push.

BT: Yeah. It has to resist the outward push. Either by having buttresses on the outside of the walls, like a Gothic cathedral, or just having a simple steel tie holding the two walls from being pushed apart are the major ways of dong it. But, the fact of the matter is that while steel beams and so on are ridiculously expensive, in most of the world it's a fairly easy matter to get, get your hands on steel wire or steel rod. So that's a great deal more available than structural steel profiles.

So then you can focus on using as many of the low-cost local materials as possible, invest in the labor to build with, and then use a smaller amount of your resources for the expensive materials to put it all together with.

BT: Right. Yeah. You may have heard of Muhammad Yunus, a fellow who started the Grameen Bank in Bangladesh. He's got this very provocative way of approaching people. He says, "We don't treat the excess of any resource as a problem, except when it comes to people." You know, nobody says, "We've got too many trees," or, "We've got too much iron," or…but we have this notion of, you know, overpopulation as a problem. In ecological terms, it's a whole different matter, but he's an economist. And so he's saying, you know, having lots and lots of people is a resource, if you treat it that way. And so that has implications in terms of how you design your building, for your labor component. And it's really kind of interesting 'cause it ties into the different economics of natural building.

I'm always telling people that if you're going to and you're going to be using one of these labor-intensive methods, you have to make that aspect of building delightful enough that you can tap the free labor available for your weekend workshop, or something—and this is where something like the earthship falls down, 'cause it's a natural building technique, and it's labor-intensive, but it's *extremely* tedious to be just up there pounding dirt into tires for day after day after week after week and so on. And so, it becomes a real slog, as can a cob building if it gets too large, just because there's so much labor involved and you lose the goodwill of people after a couple of weekends of doing it. And there was a little tiny cob building that was built as a garden shed for a community garden here in Berkeley, and it was designed by an architect I know and…And it was a very cute little building and actually a very modest thing, but they had a and the wall got up like three feet and they had another workshop, **(25:00)** and the walls got up about four and a half feet. And after that, it was just this slog for the dedicated core of gardeners who had to be out there mixing up the cob and getting it on the walls. And they finally got it finished, but it was like this, "Ughhh, we got it done," kind of quality.

But it's again one of the nice things about straw-bale construction, is that it is so lightweight. That it goes up *really* quickly, so it's *perfectly* suited for a community wall raising, 'cause it goes up fast and you can get it done on the weekend, or, if you're depending on volunteer labor and the good will of people, it's perfectly suited to that. Provided that you have sufficient supervision, that you're keeping your corners plumbed and all that kind of thing.

It was one of the points raised to me in a conversation with Dave Jacke recently, is the building the appropriate social structures in order to get things like this done. And, as you mentioned, knowing what, what kind of labor force do you have to do something like this and what is their dedication and devotion to the project.

BT: Yeah. The fact of the matter is, at our, the pace of our culture is such that people want to see results quickly. It's just sort of a fact of life. And this affects your choice of the material techniques that you're using and also affects the choice of your scale. Dancing Rabbit, I got brought out to Missouri to work with the Dancing Rabbit Ecovillage when they were just getting started. It was a group of them who were living communally and so they wanted to build a communal straw-bale house, which in resource terms seems like the efficient thing to do, you know, everybody gets their own bedroom, and they get to share facilities downstairs, and so on.

However, it was really very instructive to watch this two and a half story building—and a fairly sizable thing, as there was a number of people living in it—but it was *really* difficult for them to get that thing topped off using the workshop labor kind of model, whereas there were people who came in and built themselves a tiny little cottage, and got it done and got on with their lives. It really gave me pause, because I'm very much a—got an urban orientation to most of what I'm focused in the way of the built environment. But I realized in parcipatory terms, there's limits to that kind of thing. Well, it just comes back to this business of when the economics is such that you're depending on the good will of volunteer labor; that poses constraints on what you design.

One question that I have about the Catalan arches. One of the things, just as you were mentioning, I was looking at some pictures of them, they reference that Catalan arches don't need to be centered. Is that related to the framing that you were referring to in the other arches?

BT: Yeah. The term, it's called centering, but what they're talking about is—the other term for it is falsework, meaning, that's the medieval term, which means you have to build a form for the materials to sit on while the mortar that holds them together hardens, is the traditional way that arches were built. And there were a variety of ways of doing it, but most commonly what they did, there was a wooden falsework that was put up and supported on posts and then you stacked your bricks or your stones, or whatever, and when the mortar had set, it held all that together, you pulled the falsework down and hopefully re-used it somewhere else. But a great deal of labor and work goes into this falsework that holds the material up while it's curing, and so the fact that you don't have to use this centering, or falsework, that you can just get the shape with the few boards or—when string does, and so on—keeping your profile accurate to give you the structural results that you're after. There's a huge savings in construction terms.

Years ago, when I was a Boy Scout, we went through and built some arches and one of them was just to kind of do it free-form as it was standing. And we had, I don't know, probably six or seven people just there trying to kind of hold the different pieces in place until we got the arch complete and were able to put in the keystone.

BT: Mmhmm.

And then being shown, "Okay, well now let's build this horizontally on the ground on a board. And then once the arch was in place, all we had to do was lift the board up and then it was freestanding. And I can imagine having to build that falsework to get that in place.

BT: Yeah. It's a piece of work.

When you were talking about roofs, what kind of materials are you looking at for actually, like, sheathing the roof with? A lot of the recommendations now that I'm seeing are for a metal roof or for slate, because of how long they'll last.

BT: Oh, yeah. The actual roofing material itself. I would say in, in natural building, the **(30:00)** two leading contenders are exactly those. Metal is what gets chosen ninety-nine percent of the time 'cause it's economical. But, yeah, if you can take the weight and you can get it in your budget, slate is even more permanent.

Some of the advantages of metal roofing, however, are really attractive. One is that the water that comes off it is really clean because materials don't tend to lodge in the roof, so as long as you, your first wash off the roof gets disposed of, what follows it is really quite clean. Another is that the material steel is infinitely recyclable so it's not like you're throwing away the material when the roof wears out.

But a third one that I enjoy a great deal is that if you use a metal roofing profile called a standing seam roof, which, as the name implies, you've got these ribs every usually fourteen inches. Number one, there are photovoltaic panels, the ones called amorphous panels that literally come as a, in a roll. It's like a peeling stick, like contact paper. And these things can just be stuck onto the roof between these ribs and you get a very, very low profile, unobtrusive solar panel up on your roof. In fact, we've installed this on several projects and people come to see the project and they say, "Where are the solar panels?" And we just have to say, "See those black parts of the roof? That's the solar panels." So it's very nice that way. That's only the PD, if you're producing solar hot water, you do need a rigid panel for that because of course you've got to circulate the water through it. And, those solar panels can simply clip onto the ribs of the roof so that you're not drilling holes on the roof to mount your solar panels, which is a very clean and elegant way of doing it.

So I'm, ninety-nine percent of the time when I'm working on a rural, rural building, the recommendation is to go with the standing seam metal roof. I did have a client kind of bring me up to it, however. And remind me that, in the long term, you want to be concerned with what pigments they are coloring your roof with, 'cause if you're going to use the water off of it, after the initial finish has worn off the roof in ten years' time or so, you're actually getting bits of the pigmenting material in this rainwater that you're harvesting off this roof. And so, the beautiful green roofs that I was specifying for my projects were putting cadmium pigments into peoples' water supplies, which is not a good thing.

It's one of those little pieces that I wouldn't have thought of in that.

BT: Exactly.

Something like an asphalt shingle roof, you know, you're, I see the little bit of that material wearing off every time whereas with the metal roof—what about other roofing materials, like cedar shingles?

BT: If you were in a situation where, you know, you were just sort of going out into the wilderness with your axe, cedar shingles would be perfectly appropriate. But, the fact of the matter is, in a situation where you have other choices available to you, a wood roof is just not that great a choice. Particularly, here in California, I watch what our semi-desert climate does to wood, and it just eats it here. The way it dries out and splits and cracks and so on. So, it's really tough for me to recommend wood as a great choice when you're considering longevity. But, then when you consider the susceptibility of it to fire, it becomes even less attractive. You know, the fact that these are just little tiny pieces of kindling up on your roof, it makes anything in the way of a wood shingle extremely susceptible to a fire. And yes, you can chemically treat it, but then you're getting back into the toxic issues that we went into natural building to avoid! And so, I've never recommended—in fact I've recommended to a great deal, during a great deal of renovation work to…I'm always looking for excuses to get the shingles *off* of the roof and to replace it with something more fire-proof. 'Cause it just represents a huge liability. Particularly as our climates dry out.

So really, of the choices that are available right now, a metal roof, or, if someone can afford it, a slate roof, are the best choices available?

BT: Mmhmm.

I was going to ask you about thatching, but I think that I can leave that one alone [laughs].

BT: I *loathe* thatching. You know, when I **(35:01)** show people pictures of, you know, when I'm trying to get a sense of where they are in their sensibilities on the building we're designing together, thatch is always a drop-dead favorite. People just *love* the relaxed character of a thatch roof. And so, informally, I've spent a fair amount of time thinking about how you can get that kind of relaxed, easy nature out of a roof. Thatched roof, if you can find the materials for it, you generally—you know, there's a woman, Diane Bednar in Michigan who has made this something of a cause of hers. And she's successfully done it, you know, she's found places where she can harvest the marsh reed that makes the best thatch that we know of in the world. And she's built a small studio doing it, and it's gorgeous! I wish we had more opportunities.

I've—there was a tradition of thatching roofs on the islands off of Denmark in seaweed. And I got really excited for a while thinking about the possibility of seaweed thatch here in California because the seaweeds are so mineral-rich that they tend to sort of have their own flame retardant; they don't burn particularly well. But it turns out, a fellow I know who is Danish comes from those islands, he grew up there. And it turns out that their seaweed is not your normal seaweed, it's an annual grass; it's not the kind of perennials that normally cling to rocks along the coastline. And so on. So it's particular to those islands, the annual grass gets washed up in *huge* heaps on the shoreline every year and you just have to gather it up and dry it a little bit and then sort of spin it into these sausages that they make into their thatch, but…It's a great idea when we thought of it.

Anyway, the idea of sort of scouting the world for materials that can be put up in a manner like thatch is still a favorite little bug bear of mine, and there was an article in the old book of Lloyd Kahn's *Shelter* about a technique that they were using in East Africa back in the British colonial days. It really had me intrigued, because what they were doing was they were laying out reed; a marsh reed turns out to be the best kind of material that we use traditionally, 'cause it's better than the wheat stalks that were otherwise used. They, the marsh reeds last longer.

What they would do though is they would lay out these reeds on a table and then comb a clay plaster into it and fold it over a batten and comb it in and basically produce, they were producing a clay-straw shingle; giant shingle. And then when these things had dried, they would put them up usually fastening them with the batten, which takes a lot of the labor of fastening down out of the thatch, which is a whole skill set you have to learn. This way you're just nailing up battens.

And what would happen, apparently, is the grains would wash the clay surface off of the surface and leave exposed straw. But this straw was then embedded in this clay matrix so it wasn't so susceptible to rot and certainly wasn't so susceptible to fire, as normal thatch is. And so I thought this was a particularly good example of really getting into the nature of your materials and without recourse to, you know, chemical fixes. Coming up with a new approach to, to roofing, that had a lot of promise.

But I haven't really had the opportunity to pursue it since.

I have a copy of, I believe it's called *The Thatcher's Craft*. And, now you have me thinking, with doing that straw in a clay matrix, as the top layer washes off, then the straw on top protects the clay and other material beneath.

BT: Yeah. You've got a weather layer protecting the matrix underneath.

In our last conversation you said why—paraphrasing here—why go off and despoil a piece of land that doesn't need us? That we can go and find a solid building in a city somewhere, and then renovate it with natural materials.

BT: Right.

The home renovation question is one that still rests with me. But listening to our conversation, it sounds like the things to do for home renovation would be, well, if you need a roof, then go with a metal roof or put slate on it if you can afford it and the roof will bear it.

BT: Mmhmm.

That we should consult with local experts on how and where to insulate within our home based on our climate.

BT: Mmhmm.

And that, without needing to put in a lot of windows for (40:00) **solar gain that we, there are other ways we can add mass to the interior of a home in order to make up for some of those differences.**

BT: Yeah. Or, there's this predilection in natural building to create massive walls. And, I think that has everything to do with people being in reaction, and rightly so, to the thinness and, what, the lack of emotional satisfaction to a two by four wall with drywall on it. You know, we just don't like that as a wall. It just feels like a taut membrane with holes cut in it, and so you get this big two-foot thick wall, and it's got gorgeous reveal with the windows, and it does things with the light, and the window sill is a place you can sit. It's all got these wonderful emotional satisfactions to it. But, you really want to concern yourself with the performance of the wall as well.

But the fact of the matter is, now that we've got this, we've got the, this backlog of industrial buildings that exists already right now and they're doing a fine job of getting a structure over your head. So the point about it is, you don't have to start from scratch to get a building with character. If you've got an existing building with good bones to it, you can wrap it with natural materials, and particularly natural insulation, and get that thick-walled, snug character that you're after *and* get a high-performing building while you are doing some repair of the earth rather than imposing yet another building on it.

What are some of the natural insulations that you look to, some of the materials for someone who has, say, a two by four stick-built house? If they wanted to retrofit some.

BT: Well, we had a really interesting case this last year where I joked with friends that I was renovating a house that hadn't been built yet. I was brought in on a job when the permit had been issued for the plans and the foundation had already been poured, but the owner had gotten set up with the architect and let him go. But they had said to a friend of mine who's a plasterer, "We would like this house to be very soft and organic looking, in spite of it being a stud frame house." And, so, she said, "Well, unfortunately the plaster's just the skin, you need soft, organic looking bones for it to have a soft, organic looking plaster.

So she brought me on the job, and the two of us spent some time thinking about this. And what we came up with was we took two layers of an insulation that's very common in the rest of the world, industrial world, but not well known here. It's called 'mineral wool'. And believe it or not, this is a material that where you literally melt the salt and spin it into threads, the way we do with fiberglass glass to create fiberglass insulation. But, unlike fiberglass, mineral wool isn't a suspected carcinogen. And, more importantly, as far as I'm concerned, it doesn't evaporate in the presence of a fire, so it's actually a high-temperature insulation.

So what we did with these, they're sort of halfway between that, the fluffy things that we know as insulation, and rigid boards as insulation. They come as boards, but they're loose, flexible boards. And what we did is we put two layers of one and a half inch thick boards on the outside, screwing them into the plywood sheathing, and by scoring it, we were able to wrap it in smooth curves around the corners and do returns into the windows, and so on.

We joked—we presented this at the International Straw Builder's Conference in Colorado as a really successful way to faux-straw-bale. But it had huge advantages for the building. Number one, the best place to put your insulation is out actually exterior to all the structure, for—it's a rather complicated story, but by putting it out there, you remove any possibilities of condensation within the stud wall due to the air leaking from the inside to the outside reaching the dew point and so on. So, you've put the insulation in the right place, because it's a high-temperature insulation it's actually making the walls less susceptible to fire from the outside. In a situation like this, in a rural situation, where wildfires are your primary concern, it's a great substrate for an earth plaster, so you don't have to add lathing to the outside of a plywood wall. And it allows this kind of organic character to the place.

So this is a great way to insulate **(45:00)** a place and retrofit a stud-frame building and soften it at the same time. So that was one of my big discoveries, is doing it with mineral wool. So, I think you're going to see a lot more mineral wool in this country because it's got attributes that really argue for it over fiberglass, which has been our standard for a long time.

Cellulose insulation is an absolute winner for our wooden structures, as we know them now. You know, particularly the ones where you since, what, the last twenty or thirty years, most tracked homes and so on have prefab wood trusses dropped on top their stud frame walls which means there's this attic space that's largely useless because it's full of these, all of these cross struts and so on and of the trusses themselves. But what that means is that you can go to Home Depot and they will loan you one of these lower things, and you buy a few bales of ground-up newspaper, and you can just throw eighteen, twenty-four inches of insulation up there into the attic space and do a great job of making your home far more energy efficient for very, very little money.

It's true that cellulose has to be treated with a borate solution to make it fire retardant. But, as fire retardants go, borate solutions are relatively benign. So I'm not terribly uncomfortable with recommending it.

Besides those, those are the major ones that I'm excited about nowadays. I'm convinced, however, that over the long term, you're going to see rigid foams be made out of vegetable oils rather than petroleum products and, you know, I've had this argument with architects for a while, they're trying to stay away from rigid foams because they're petroleum products and they're flammable and they have flame retardants in them and so on and so forth. You know, they're not great when you consider the toxic character of them. And my point about it is that these are placeholders while the soy oil-based rigid foams get developed. And they are actually in the works, so I think you're going to see more of those.

But the fact of the matter is, that mineral wool the thing that I described as this relatively fluffy material, also gets used in denser, more rigid boards that can be used almost everywhere that foam panels get used. The primary place where you need more rigidity than the nine pound per cubic foot mineral wool that we used on the walls is up on the roofs. Because in the same way that it makes sense to put the insulation outside the structure of the walls, it makes sense to put the insulation outside the structure of the roof.

So, contradicting what I was talking about about pumping all that cellulose into your attic, in life cycle terms the ideal place to put the insulation of your roof is above the roof deck. But in order for the insulation up there to actually accept the roofing over the top of it, it's gotta be a dense enough material that you can actually walk on it and not compress it and nail into it and it'll hold roofing material. And so on.

So. This is where the insulation becomes the most valuable is if it's simultaneously full of the air spaces that are, that give us insulation. But the matrix that creates those air spaces is rigid enough that it can be formed into a kind of board material. So, the ideal in those terms is actually cork: Annually renewable, it's all-natural, it's rigid enough to be a board, and so on and so forth. And I was very pleased that—what was it—about two years ago, there was a company that announced that they are producing cork insulation boards. You know, previously you just had to buy cork sort of as it came off the tree. Which was really expensive. Now they're taking the cork granules that are left over from producing the corks for wine bottles and so on and they've discovered that when you heat them up, they expand and they release some lignin so that it'll bind itself together into a board without the use of an additional binder.

So this is a really exciting development because it's, as I said, it's all-natural material with very, very low embodied energy in it, and quite good performance. So we just had to kind of wait for the price of this stuff to come down because now it's something of a boutique material. But it's a perfect example. And as far as I'm concerned, if we went looking, we could probably find something besides cork oaks who are producing something **(50:00)** light and fibrous and relatively inert this way. But we just haven't been looking for it.

And I'm looking at the semi-rigid cork insulation, and it looks that the—oh, what is it—four—oh, soon as my ability to do math kicks in [laughs]—for about seventy-two board feet is about $200. So, for one inch thick. So that's—

BT: It's still pricey.

But to know that it's an option, and again as you say, if western society invests in these methods, then, not only do we get the scale that comes from that to help lower those prices but we also get to learn different techniques that can be used elsewhere in the world.

BT: Yeah. I mean, that's what's so exciting. I get as impatient as anybody else at how slowly we are moving at changing our direction in this regard. But, the fact of the matter is that it *is* changing. You know, my mental metaphor is, "Turning the direction of the super-tanker." There's just so much inertia involved in, in the direction of our civilization that it takes a long time, but we're now watching this change happen and all of the ingenuity and drive and, and initiative of this civilization is *slowly* changing its focus to say, “Okay, how can we do what we like to do in a way that is more benign, and ideally is actually restorative to the earth?” You know. And so, it’s very exciting to watch that happen, you know, *every month* somebody has come up with some brilliant new take on the way we’ve been doing things for decades; you kind of slap your forehead and go, “Of course! Why didn’t I think of that before?”

It’s going to be interesting if these ideas accelerate. What other new ideas—or rediscovered old ideas—become part of our toolkit moving forward.

BT: Oh yeah. Yeah. No, there’s—you’ve probably seen this website ‘Lowtech’. And it’s a perfect example of exactly that, you know. People just kind of mining history to say, “Back when people didn’t have the luxury of fossil fuel subsidies, they were *really* thinking about, okay, how can I do this efficiently?’” So there’s this great example of wire transmission. If you’ve got an energy source like falling water, you know we automatically think that you run a generator and turn it into electricity. And electricity is a very flexible way of transmitting energy, but the fact of the matter is that you can, for *far* less in the way of investment, you can just put up a paddlewheel that creates a wire that is rocking back and forth along its length, and it’s really, really easy to transmit power. You know, you’re not going to send it across the country in this way, but in terms of energy invested, a farmer in Pennsylvania could set up a simple water wheel doing this and get this rocking wire going and then discover that he can hook up all kinds of really simple farm machinery to it, you know, so that he can run his milling machine or other simple devices to this rocking wire. That kind of thing is, I think, what we’re now sort of going back and looking at.

And the fact that a recumbent bicycle with a fairing over it is vastly more efficient than the bicycle that we’re used to. And, you know, recumbent bicycles have actually been around for a long time. But, we now have the materials to put a fairing over the thing to make its wind profile really, really efficient. And now people are saying, “Well, you know, you take that basic armature of a person in a semi-recumbent position on an ultra-lightweight frame with an ultra-lightweight fairing over it and then put an electric motor on it, and you’ve got something that’s ninety percent more efficient than your normal electric car.” But what is it? You know, particularly if it has a pedal assist, is it a bicycle? Is it an electric car? It’s something halfway between the two.

Well I have to work on answering those questions as we move forward, and find more solutions and go, “Well, I want to put this on the road, what is it classed as, do I need a license for it?”

BT: Right.

I wish that you lived here on the East Coast, sir, because I have so much renovation to do in my own house and I’d love to pick your brain for hours. But, as we bring this to a close, you have any last thoughts for the listeners?

BT: Let's see. Other emerging technologies for people to look at…I shouldn't call them emerging, actually they're mature technologies; they're just emerging in our market here. There's one called 'aerated **(55:00)** autoclaved concrete', or EAC. It's been around in Europe since the 1930s. And when I first discovered it as a student, I thought I'd seen the miracle material. But it's now slowly being introduced into this country, but what they are is these large blocks of very, very lightweight porous concrete. So they're completely inert and fireproof. They're a little brittle, again, in seismic situations it's a little problematic, but for a great deal of the rest of the country, it's a *great* addition to the language, as I said, of creating a massive-looking wall that is A, inert—both for insects and moisture and for fireproof. But, B, is quite insulated. And there was an article in *Fine Homebuilding*, one of the issues recently, that extolled its virtues. So that's something for people to be aware of.

There's another one we're using on a project now that was *really* counterintuitive when I first saw it called cross-laminated timber panels. This is a technology again coming out of Europe where they're taking wood—it's a little bit smaller than a two by four, it's their basic size—and they're gluing them together to create a panel and then running them in different directions. So it's sort of like plywood on steroids, you know, plywood is veneers of wood glued together running in different directions to make an extremely strong product.

Well, imagine doing this but instead of veneers you do it with two by fours. So you glue it together a sheet of two by fours, glue on top of that another sheet of two by fours running in the opposite direction, repeat that as many times as the strength you need, and you get something that has most of the strength of a concrete slab for one sixth the weight of a concrete slab. And these get prefabricated in a factory and shipped to you. And there are architects who are grabbing this with both hands because they see opportunity in a material this strong, with not just a low carbon footprint but actually sequestering carbon in the process. And so there are, there is a nine-story building that was built this way in downtown London, and because the panels are prefabricated, it goes up in weeks instead of months, and it's a very promising technology.

When I first saw it, I said, "Damn, that's a lot of wood!" You know, for those of us who are used to stick frames. But, the fact of the matter is, in, particularly in cases like the Pacific Northwest where beetle kills are decimating the forest up there, we have this unique opportunity right now that if that wood can be harvested and good to use, we're sequestering *huge* amounts of carbon. But it has to be done while the wood is still on the stump because once it rots, of course, it releases the carbon back into the atmosphere. So we're in this situation right now uniquely where if we [laughs] if we use as much wood as possible as quickly as possible because of this one unique phenomenon where our forests are, unfortunately, adapting to the different temperature profiles induced by climate change.

But, anyway, very interesting technology. We are using it on a project here in Oakland where we're producing a bunch of straw-bale row houses and the cross-laminated timber panels are going to be the floor of our second floor and they're also gonna be the shear panels. I, my joke is what we're doing is we're putting up this little house of cards using these CLP panels and then putting a straw-bale wrap around it. But it's a perfect match of technologies in that we get the super-insulated envelope around a very quick, efficient, prefabricated frame.

And I think about the cross-laminated timber panels the possibility of doing things like recycling palettes to use as lightweight kind of junk wood to potentially build a building material.

BT: Yeah.

So many options and so many opportunities. Thank you, sir for spending this time with me. I think that I can sit and talk with you for days and days to learn firsthand about all these different techniques and materials. I really appreciate you coming back for a second time to sit and talk with me. Thank you.

BT: You're most welcome.