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Abstract. Werner Schmidt (Trübbach, Switzerland, 1953) is one of the most interesting contemporary 'green' architects, particularly experienced in straw-bale building. His accomplishments include now 20 straw-bale buildings of which 14 at least partially load-bearing.
This paper extracts some essential principles from his work and explains in detail his technological solutions. This is the result of a thorough analysis, carried on during the preparation of a monograph.
The success of his approach derives from many factors, among which:

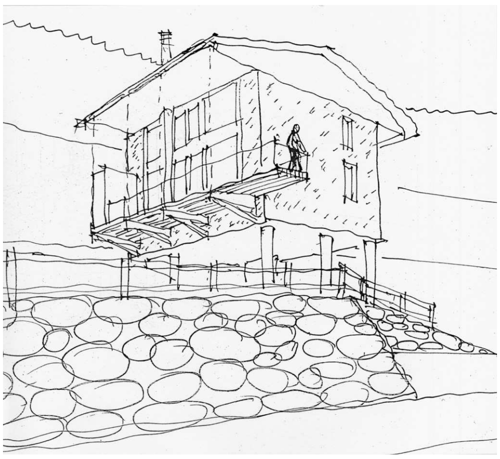
- Schmidt's training as a mason. In contrast with many fellow architects, his designs are rooted in practicality and feasibility. Moreover, he actively participates to the construction work.
- His holistic vision of ecological building: straw bales are chosen because of the overall advantages they offer. Preferably, he adopts a modified 'Nebraska' technique, using high-density 'jumbo bales' forming more than 120 cm thick walls. This rather unique method assures rapidity of construction, and allows to solve a number of criticalities associated with 'small bale' building.
- Not seeking the highest possible performances lets to focus economic and technical efforts on few elements that really need to be state-of-the-art. The envelope can be built with simple technologies, while parts that need be built precisely (stairs, cooking implements, baths, etc.) can be prefabricated.

Schmidt's work shows that high ecological consideration can be coupled with convincing architectural results. The quality of his buildings in term of energy performance, living value, and beautiful form constitutes a good practice promoting new ways to 'green' architecture.

Introduction

Werner Schmidt's training as a mason has deeply influenced his later work. In contrast with many fellow architects, his approach appears outstandingly rooted in practicality and feasibility.
In Schmidt one finds an obvious continuity between formation and professional practice. Far from being ashamed, he indulges in 'dirtying his hands' both metaphorically – i.e., dealing with the building site problems and minutiae during the design phase – and literally – actively participating in the construction of his buildings. This is very evident just seeing one of the short films he usually produces to document the making of his buildings, from which one can learn better than through a handbook or a lecture how to erect a straw-bale building.
True, the architect's direct involvement in the building work might be the consequence of using an uncommon technique, albeit easy to learn. But for Schmidt, conception and manual competence are inseparable. Intelligibility of and familiarity with the physical world are pre-requisites for taking responsibility towards it, as Crawford has acutely observed [1:8]. Doing manual work, he points out, cultivates attentiveness [1:82] and increases the "sense of agency and competence." [1:5]
Schmidt soon showed an interest in designing autarkic, passive buildings. In the last decade, the solution he has most often used to achieve an extremely high insulation performance of the building envelope is employing straw bales; although this can be obviously attained with other materials. For instance, in the Tarcisi-Maissen extension (1997), a 60-cm cellulose insulation was used; house

Schmid-Cavegn (1998) is almost identical to the houses Schmidt designs today, but for the insulation used (in that case, it was mineral wool).
Schmidt recalls that the origin of his interest for straw-bale construction dates from about 1995, when an acquaintance gifted him the Steens's book on the subject [2]. In 1997 or 1998 he built a 1:1 prototype in the yard of his father's workshop, who was a master builder – a corner-shaped straw-bale wall, 4x5x2.5 m, with a window and a door. The final comment of his initially sceptical father – "not bad!" – certified he had passed one of most difficult tests. After having gathered the information then available, in June 2001 he resolved to make a study trip to New Mexico, where he attended a course in natural building and permaculture at the Lama Foundation. He also visited a number of straw-bale buildings in the region.

1 

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Soon afterwards, also thanks to the help of Peter Braun – the client's brother and an engineer who accepted to act as a consultant for this project –, Schmidt could build his first straw-bale house – the much-celebrated and iconic house Braun-Dubuis in Disentis (Fig. 1-2), that was completed in 2002. After this commission, clients tended to come to him because attracted by the advantages of the new material. Since then, the list of Schmidt's straw buildings has been growing quite impressively – it includes now 20 works in three countries – and more are in their way, including a 'zero carbon village' in Lower Austria, in cooperation with GrAT (Gruppe für angepasste Technologie [Group for Appropriate Technology]) of the TU Wien [Vienna University of Technology].
In his designs, straw is used in different ways, including both load-bearing and non-load-bearing techniques, often with hybrid solutions which make use of structural timber and prefabricated elements. From the technological point of view, there's no such thing as a 'typical Werner Schmidt way' of employing straw – on the contrary, one could say that every new project is an occasion for further improvement and experimentation.
Schmidt gained much of his knowledge about building with straw bales through direct experience, but it is also worth mentioning that he connected quite early with GrAT (that since 2000 has been conducting tests on this material), and that he co-operated with the HTW Chur [Chur University of Applied Sciences] where further tests were conducted on flammability and compressive strength.

The reasons for a choice

All materials offer possibilities to the builder. Schmidt has used various materials both for structural and insulation purposes – those used for the latter include polyurethane foam, rock wool, cellulose, EPS, foam glass, wood fibre board, cork, expanded clay, vacuum-fused fumed silica. It was his experience with various materials that convinced him to give preference to straw, as its characteristics best adhere to his principles. Schmidt's choice, far from stemming out of an ideological *parti-pris*, is grounded on the conviction that ecological building is much more a holistic affair than to satisfy low-energy consumption Passivhaus or Minergie requirements.

Straw is appropriate for creating healthy living environments and minimising the ecological impact of building process – from construction to disposal. Schmidt's goal is to realize pleasant, autonomous buildings, at reasonable costs. He explains: "The first step is always to eliminate the heating, and if you want so you need a thick insulation. If this is done with conventional insulation materials, it is very expensive because the production of these materials is dependent from rising energy prices. In straw-bale building it is not relevant, from a cost perspective, if one uses 50 or 120 cm insulation." [3] To put it in another way, "passive house" standards are attained at a much lower cost than with conventional solutions.

Most of the advantages Schmidt has found in straw bales, are clearly discussed in Gernot Minke's handbook [4]. Straw-bale building shows many similarities with traditional methods such as load-bearing masonry or cob: massive structural concept, use of little-transformed natural materials, non-toxicity, mutual compatibility, re-usability, acceptation of time passing, necessity of maintenance, search for satisfactory and not for maximum performances, minimisation of the number of layers. It demonstrates that "alternatives to modern building materials are available." [5:xi]

Natural materials do not fit modern classifications, [6:5] and their characteristics are little known in scientific terms. In Europe, just a few laboratories – among which, GrAT, the University of Bath, Braunschweig Technical University, HTW Chur – have developed tests on straw bales, and there is still disagreement about the values – even about basic dimensions [7:83]. Assigned values are often conservative, for the benefit of industrial products (see for instance the BRE Green Guide where straw bales are rated as A while EPS as A+, on the grounds that the first are highly toxic to freshwater, and get bad rankings in human toxicity, waste disposal, and eutrophication [8]). Moreover, real performances obtained making use of natural materials are often better than predicted from calculation.

In the case of straw bales, laboratory tests were often conducted on low- (90 kg/m^3) or mid- (120 kg/m^3) compressed small bales. This is one of the main reasons why Schmidt aims to perform a series of scientific tests on 'jumbo' bales – i.e., 240x120x70÷90 cm – at the gbd Lab GmbH in Dornbirn. Values such as λ, μ, compressive strength, etc., would be measured on 140-kg/m^3-compressed bales as such, and on unplastered as well as plastered walls made of such bales. These tests would scientifically investigate jumbo bales specific characteristics, that are expected to be different from those of usual, small ones. Tests will be performed on both bales made of entire straws and of small fragments (the length they are cut for animal bedding). Werner Schmidt hypothises that λ might better with short fragments, whereas whole straws offer a better grip for plastering – the plaster layer may detach itself from a chopped-stalks wall. Another advantage is that current balers automatically put a chip in jumbo bales, containing data such as production place, date, moisture, etc. Jumbo bales are also favoured by farmers, not only by Schmidt, as they can be more rapidly transported and stocked than small bales.

Obviously, building with jumbo bales means according preference to (at least partially) load-bearing walls. Schmidt asserts the load-bearing one is "the simplest and best method of construction in terms of my goals. It is the cheapest and also the best method from the energy point of view. A loaded straw-bale wall is condensed by the weight of the building," [9:9] while if the wall is not loaded, over time the straw insulation may perhaps settle down, creating a thermal bridge at the top. Other advantages include ease and rapidity of construction. As Bruce King has remarked, "a plastered [load-bearing] straw bale assembly is structure, insulation, air barrier, finish, and fire resistance all in one – as opposed to most building materials, which typically perform one or two of the requisite functions of a building enclosure." [10:xxv]

On the other hand, the adoption of jumbo bales severely limits self-building, as they need to be craned. Furthermore, the envelope of a jumbo-bale building is quite thick, which is no problem in suburban homes but might be a constraint in other cases. On this point, Schmidt observes that walls may take a lot of space, but this approximately equals the area which would be occupied by central heating room, oil-fuel or pellet tank, etc., that can be omitted thanks to the superinsulation. He details 120-cm-wide bales wherever possible, because in one hour 7÷8 jumbo bales can be craned in

place, independently of their size. Therefore, while 80-cm-wide bales provide 5÷6 m^2 of wall, 20 m^2 can be erected from 120-cm bales in the same amount of time.
Schmidt points out that "a straw bale house with a wooden structure, then with straw only as insulation, could use as well another ecological insulation material between the timbers. This is actually a conventional construction, just with a different insulating material. The realization of a load-bearing straw bale building necessitates a completely different design principle." A change of attitude is required from the builders' side too, because during construction "the house moves and reacts to what you do. (...) Most engineers and craftsmen have a hard time during the first confrontation with such a design – there are no computer programs that expect these changes during construction, you can put away your meter stick with millimetres marked on it, etc. It demands craftsmanship and common sense. This kind of design frees us from our obsession with precision everywhere, even in places where it is not needed." [3]

Prefabrication

The 'straw-bale perimeter walls plus wonder box' concept epitomises Schmidt's self-sufficient house. To put it very simply, such a house should have a very performing envelope – possibly, its area might be minimised adopting a circular plan and even a domed roof –, and a container ('wonder box') for wet areas and services for energy, water and air management. From the constructional point of view, the building envelope can be built with simple, even low-tech methods, while the inner, prefabricated unit would include those parts – stairs, cooking implements, baths, etc. – which need be precisely built. Bathrooms and kitchens should ideally find themselves inside the plan, and not adjacent to straw-bale perimeter walls. This might be one more reason to use prefabricated units.


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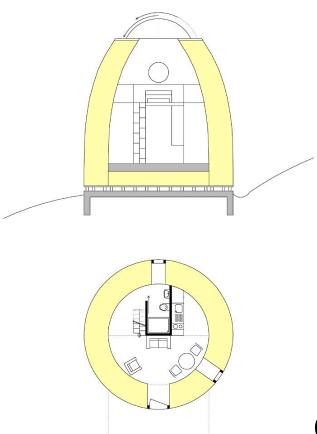
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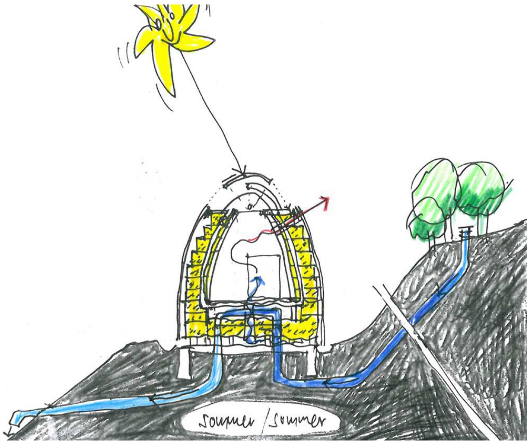
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As such, this concept hasn't been realised. So far, vonRoll Hydro training pavilion in Oensingen (2010; Fig. 3-4) is the most close concretisation, but its envelope is technologically very refined

(and expensive), because of the functions it must perform. In the unbuilt La Donaira guest rooms, in Andalusia (2009; Fig. 5-6-7), the principle would have found an advanced and consistent application.
The impossibility to build in the mountains during long, snowy winters has helped the development of woodwork prepared off the building site. In vernacular architecture, prefabrication was already a clever design response to the limits caused by location and climate. In peasant houses clarity of disposition as well as economy of gestures, money and energy already facilitated the concentration of ‘wet services.’
Schmidt often uses wood-based prefabricated parts (load-bearing structures, windows and door casements, ‘wonder-boxes’, etc.) that can be custom produced in winter, in order to keep the on-site building time as short and clean as possible. His job is organised according to the seasons – generally buildings that will be built the next year are already detailed on the previous one, so to allow the winter-time production of what will be needed to assemble them.
In Maya guesthouse in Mont-Noble, Valais (Fig. 8-9), Werner Schmidt has pushed the prefabrication concept to a new limit. During the winter months, the elements have been manufactured in Dornbirn, Austria, by Fussenegger. The two buildings have been erected in just three weeks in May 2012.

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The two-storey, elongated building near the road contains eight guest rooms. Each room is constituted by a 20 m^2 box made of cross-laminated timber plates. Boxes arrived to the site already equipped with a glass box containing the bathroom, and black stone floor tiles. On-site further work processes didn’t sum up to much more than clay plastering, cabling and installing sanitary appliances. After positioning the wooden boxes, 80-cm-wide straw bales have been placed between the rooms, on the building perimeter, and on the upper face of the last floor. Besides separating acoustically one room from the next, and thermally insulating the building, the straw-bale walls bear the roof load.
The second building, which lays on a slightly lower spot, houses the owners’ residence on the upper floor, while kitchen, office, warehouse and a large dining room for guests are located on the ground floor. Here the building method is different: Schmidt has experimented for the first time prefabricated – still made-to-measure – straw-bale infill wall panels, which were delivered already plastered on both faces.
I believe it is interesting to compare the panels Werner Schmidt has designed for this project with ModCell panels [11]. Both panels are one-storey high and are timber-framed, so to form a load-bearing perimeter wall system. Both structural systems can be compared to a platform frame construction, in that the intermediate timber slab is sandwiched in between ground- and first-floor wall panels. ModCell as well as Schmidt’s elements may or may not include window frames. Finally, in both systems joints are left exposed and clearly recognisable.

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ModCell panels are a partially standardised product, to be used in different projects. Their racking shear resistance, fire resistance, thermal transmittance, and acoustic transmittance have been extensively tested at the University of Bath, in some cases passing "with flying colours." [12] They are 490 mm deep (straw bale + render on both sides). Their planar form and rather modest volume make them reasonably transportable. The glulam frame is built first, then straw bales are stacked in and pressed down with a front-end loader. ModCell panels are reinforced with stainless steel vertical rods and corner or cross braces. They are then plastered on both sides with a formulated lime render; a final coat is laid at the building site. As it is very simple and does not ask for any particular machinery, it is possible to localise the production very close to the building site, in a 'flying factory.' Building corners are realised with special, squared elements.

Schmidt's panels are bulkier both in thickness (800 mm) and shape, as they may be planar (if to be located in the central portion of the wall) or L-shaped (at the building's corner). This makes them inherently stiffer but more difficult to transport (Fig. 10-11). The frame is here made of cross-laminated timber. No further ironmongery is necessary than that connecting the timber plates. They are manually infilled in horizontal position. These panels are delivered as already rendered: with lime plaster on the outer side, and clay plaster inside. Panels of different forms and dimensions were custom-produced for Maya owners' house and for subsequent projects.

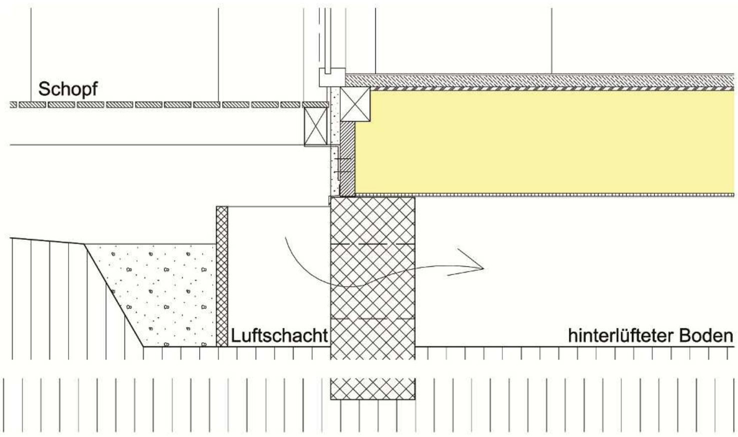
Today, one of Schmidt's main design activities consists in developing uncommissioned model houses of different sizes, from small to extra large. The aim is to work out standardised, facilitated – thus cheaper – solutions, and to give his prospective clients a firm basis with regard to costs, characteristics, and equipment. It is to be underlined that prefabrication – particularly if applied to handcrafted elements made of timber and straw – need not mean mass-production of identical parts, and the same goes for the buildings which might result from their assembly.

Werner Schmidt's straw-bale building techniques

Lacinski and Bergeron argue that "almost every [straw-bale building] project is still a custom project, with details and techniques invented during the design and construction phases." [13:11] In Schmidt's case, this is only partially true, as he is being refining solutions from one project to the next, but some tried-and-tested ones stay the same. Luckily enough, for the time being "the non-proprietary nature of straw bale building has kept innovation, refinement, and failures out in the open to learn from." [10:xxiv] Straw-bale building designers form networks, and exchange information among themselves and with the world at large. Schmidt is no exception, indeed the richness and non-reticence of the information he gives in his website are facilitating the diffusion of more sustainable approaches and techniques, and are totally consistent with the open-source character which many advocate straw-bale building should retain. His website couples visual refinement and plain navigation; and his video clips are appropriately short, direct and understandable.

In the following points I'll try to describe how a straw-bale building 'à la Werner Schmidt' is made:

- Building-grade bales are bought from recurring suppliers. The quality of Schmidt's buildings is also the result of the cooperation with a small, trustworthy building firm. At least three people experienced with straw-bale construction are requested at every building site.
- Cellars are usually avoided and excavations are kept to a minimum. So far, foundations have always been reinforced concrete: using other materials is still a goal for his future work.
- A lower drainage is provided both to protect against rising damp and to allow any water that might be found in walls and floor to drain away. Schmidt is in accordance with Jones, who recommends that waterproof layers – and above all plastic ones – be avoided, as they would hold moisture inside [14:59-60]. Recently he often happened to employ foam glass gravel in direct contact with ground, but still prefers the 'always air underneath' solution (Fig. 12). In principle, both methods allow to use straw in ground floors, which many advise against. [10:191, 13:98-109] Timber ground floors support the walls, avoiding the need for a plinth wall on the perimeter. This solution is safer in that it forms a continuous ventilated element underneath the house, and eliminates thermal bridges – Minke righteously dedicates much effort to describing how to detail this delicate part of the building [4:50-51].



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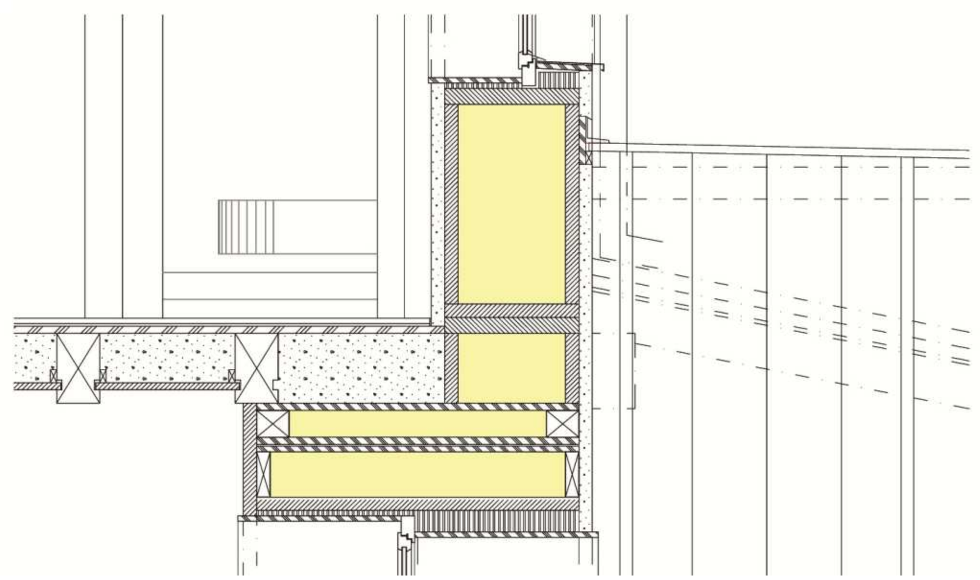
- Over floor bales, an 8÷10 cm anhydrite or concrete layer may be cast on a separating membrane or on timber boards. Dark grey anhydrite may be polished and waxed to be used as flooring, otherwise may function as subfloor, often with a flagstone or other dark flooring on top of it. In other cases the upper boarding performs directly as flooring.
- In principle, the building's dimensions are co-ordinated on the basis of the bale's, in order to minimise cuts. But in practice, actual dimensions of bales – and in particular their length – does not correspond exactly to the nominal ones, therefore one ought to be ready to manage these irregularities during construction.
- If straw bales are load-bearing, time is needed for them to displace under load. Schmidt's experience is that the full creep – up to about 15÷20 cm per floor, whereas just 10÷12 cm in a hybrid construction – will occur in the first 4÷8 weeks, finding thus the permanent configuration. Where the structure is hybrid, one-week creep is enough, but straw will not be compressed as much as in load-bearing buildings. According to Schmidt, this can be counter-productive, as it entails a higher risk of plaster cracking.
- Pinning was just used where small bales were employed. Another current practice of straw-bale building, connecting the base plate to the first course of bales with wooden stubs [14:82], is implemented using steel nails.
- Bruce King suggests to precompress small-bale walls in case of "severe loading such as seismic or high snow loads." [10:89] Once again, in Schmidt's opinion, precompression is not needed with jumbo bales. During the first weeks, the load is taken by straw-bale walls, until creep brings them level with timber structures, such as window boxes and internal load-bearing piers and/or walls, if any. Compression straps have been used only in some early

projects; they were enveloped with mesh and then plastered. Schmidt has dropped this method because straps cannot be cut away, are a redundant cost, entail a lot of work, and may produce cracks in the plaster.

- In case straw bales are really load-bearing, window frames can only be built when dimensions are stable, while in some recent buildings, prefabrication frees from creeping issues. In hybrid buildings, window and door boxes are exploited as piers and sometimes as bracing too. In any case, Schmidt uses full-depth window boxes. This "requires a lot of lumber and removes the possibility of splaying at the top and sides of the opening," [13:139] but solves many practical problems.
- In most cases, windows are wooden-framed and triple-glazed. To avoid thermal bridges around windows, Schmidt uses cork panels, sheep wool, or reed mat against the outer side of the framework.
- Moisture and waterproof membranes are avoided. Schmidt designs 'breathable' building envelopes, without caring to detail an increasing vapour permeability of the wall from the inside to the outside, as theory would require. [13:42] In his opinion, what counts is that any moisture that might be found in jumbo-bale walls can escape when summer comes, following the same principle as in traditional architecture built with natural materials.
- Jones states that plastering over meshes "is totally unnecessary and a waste of time," [14:97] which is true if they are meant as plaster meshes only since straw offers a very good grip. In the USA, meshes are used for structural reasons, particularly so in earthquake-prone areas. Sometimes Schmidt too uses them for reinforcement, but the main function he attributes to them is to reduce the risk of cracking in plasters. A number of authors – including Minke [4] – recommend not to insert metal elements in bales and plasters, to reduce the environmental impact, and above all to inhibit condensation and rusting: two phenomena which might threaten the walls' durability. Usually, Werner Schmidt employs galvanised steel mesh, sometimes fibreglass or vegetal fibres. Schmidt claims he has never experienced problems due to the use of metal meshes.
- There are 3÷4 plaster coats, totalling 20÷50 mm. On the outer face of perimeter walls, Schmidt generally employs lime plasters, which are left untreated. The inner face is clay- or lime-plastered. Air tightness is obtained with plaster and adequate detailing at joints – openings, electrical junction boxes, etc.
- Intermediate floors differ from one building to the next. For instance, in house Braun, it is a cross-laminated timber plate, which functions as flooring as well; in house Fliri (Graun im Vinschgau, 2007), the brettstapel structure is topped by fleece, sound insulation mat, membrane, anhydrite subfloor, and brick flooring; in house Schmidlin (Wahlen, 2004), wooden beams carry the flooring and the space between them is filled with an earth screed (Fig. 13). As a rule, first floors interrupt the perimeter walls forming a ring beam, like in platform frame construction.
- Not load-bearing, partition walls are often constructed with unfired bricks to maximise humidity regulation.



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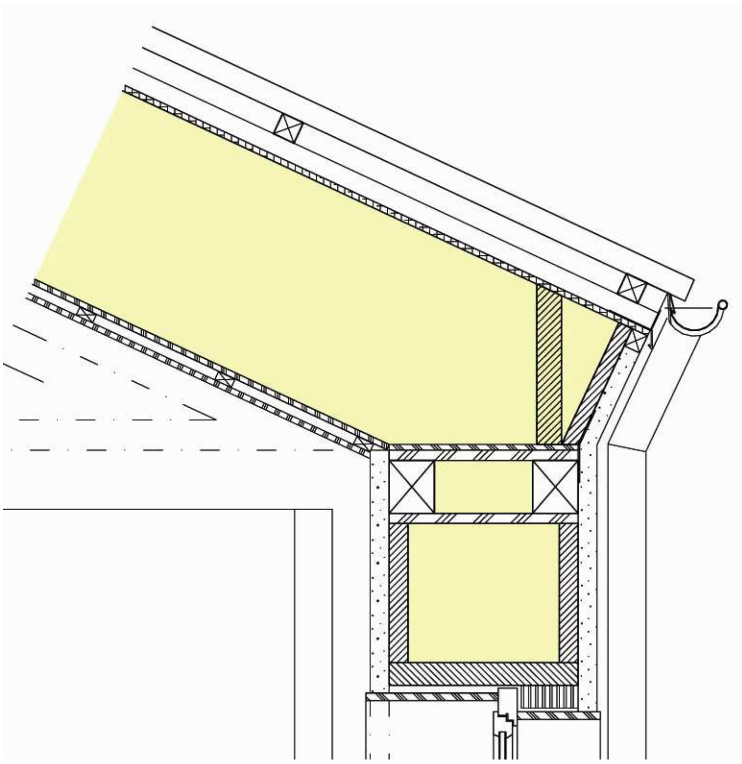

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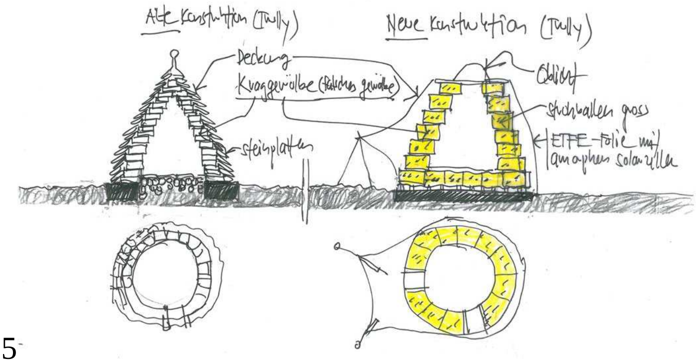
- Roofs are almost always pitched, and may contain a very thick straw-bale insulation layer or not. If not, this is placed above the last floor and the attic is not inhabitable; if so, their timber structure is similar to those Schmidt often employs for ground floors. As several authors recommend, the roof structure lays evenly on the load-bearing or ‘hybrid’ wall system, through a roofplate (Fig. 14) [4:55].
- For roofing, Schmidt has used metal sheets, roof tiles, FRC boards, etc. In a few cases, the roof is flat.
- Schmidt does not employ mechanical ventilation, as it is not necessary. Schmidt holds that in a healthy house as those he builds, the problem to expel toxic substances from the indoor environment does not exist, and excess moisture is regulated by clay plasters and other porous materials such as wood: therefore it is sufficient to open the windows every now and then to change stale air.

- Stove uptakes are placed outside as much as possible, because although well insulated they can bring cold inside, and under special meteorological conditions cold air risks being sucked inside. Usually there are no suction fans in kitchens and bathrooms. Carbon filters are used instead, to even moisture out and absorb bad odours.
- Schmidt prefers to chase pipes into partition walls, not in straw-bale walls [4:58], and have they run in a central conduit in every floor, from which all wires are derived. This layout is rational as well as inexpensive, but clients usually want a more ramified electrical system.

One can argue that, if it is built by a company, a straw bale house will cost about the same as a conventional house. However, Schmidt judges that the construction of a simple load-bearing straw bale house is a little cheaper than a comparable conventional building. If what counts is cost, rather than construction time or precision, he thinks it is better to superimpose a bale on top of the other and wait for creep to develop fully under load. This is the method he favours, both because 'truest' to the straw-bale building approach and because the building will be healthier (for lack of glues in wood-based products) and have a lower embodied energy. On the contrary, when the building is to be finished in a short time, he may use straw just as insulating infill in a prefabricated timber construction, and the house will be more expensive. However, it must be remarked that the construction system affects only partially the final cost, which depends more largely from finishes, equipment, and labour.



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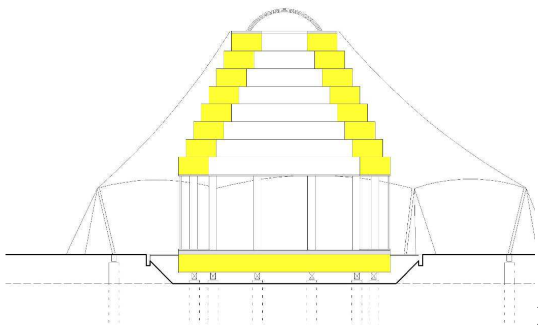

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Schmidt is working much on the development of the concept of a really inexpensive, low-tech solution: a 'casa cabana' (Fig. 15-16) made of jumbo bales, whose building envelope would be almost without timber – the roof would be a straw-bale false dome (like in Apulian trulli) or false vault, protected by a detached, waterproof membrane (like in vonRoll pavilion). All services would be contained in a 'wonder box' technical unit placed inside the living volume. This concept is nothing else than the development of the trulli-like living units designed for La Donaira.

Structural concept

Engineer Peter Braun from Fribourg is the brother of the first client who commissioned Werner Schmidt with a straw-bale house. Braun is a rare case of engineer who does not hide behind a computer or a standard, and who takes responsibility of his judgement – and in doing so attempts innovative ways.

Braun's structural approach is based on risk analysis, in his opinion an "experimentally clean" method. [17] He clearly states that a structural designer must differentiate "between load-bearing capacity, which must be guaranteed, and serviceability, which can be negotiated at a certain extent." [15:113] "Since one cannot see forces – he explains –, one must establish a model," but this won't be enough to guarantee the success of the structure, as this is achieved by a mix of calculation, experience, and fine-tuning on the building site. The latter has been the result of Schmidt's work, whom Braun likes to cooperate with, also because "he can reason as an engineer." [17]

So far, tests could not determine an ultimate strength value for straw bales. In Braun's opinion, the limit load must be over 15 t/m^2, the value obtained at the HTW Chur. [18] However, the structural

behaviour is determined by the modulus of elasticity, which is approximately 0.4÷0.6 N/mm^2 according to both FEB Kassel [4] and HTW Chur. Thus, according to Peter Braun's models, a 3-m-high, 80-cm-wide straw-bale wall can bear a maximum load of about 6 t/m^2. At higher loads, the wall buckles. This means that at loads of 3 t/m^2 there is a safety factor of 2, which is sufficient.
King asserts that "neither the straw bale walls nor the plaster skins could perform in the same structural fashion individually; the sum is greater than its parts" [10:21] and Braun agrees, as his experience makes him think that the (1÷2 cm thick) transition layer where straw is intimately mixed with plaster is crucial in determining the whole structural system's behaviour. Although not modelised, the recognition of this phenomenon implies a different understanding of straw-bale walls than as sandwich panels or weak stressed-skin panels, like King suggests [10:66-68], because the solutions Braun has been developing with Schmidt differ from USA load-bearing systems in two relevant issues: 1) bales are denser; 2) they are larger and therefore walls are thicker. Ring beams are dimensioned so to rest on straw bales only, therefore the vertical load carried by plaster must first pass through them.
Braun assessed 40 kN/m as the permissible load for a 120-cm-thick wall. This was obtained halving limit load – as in timber structures –, and is very close to the value given by FASBA. [19] Facts seem to demonstrate that the theoretical value stipulated by Braun was still conservative. For his brother's house in Disentis, Peter Braun designed the structure so that operating load did not exceed 30 kN/m^2, whilst the plaster's function was mostly to brace the wall. Actually, under heavy snowfall of winter 2006 total loads have been 23 kN/m (dead load) + 19 kN/m (live loads) = 42 kN/m, which gives that load in plaster has been as high as about 0.18 N/mm^2 – as apparently such overload could not be carried by straw bales. In fact, straw is elastic: If it took the weight of snow, the house would compress in winter and spring back again in summer. Actually, no moves are apparent. This means that the snow load is entirely taken by the plaster – or that the combination of the two materials can actually carry more than theoretically expected.

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The experience of house Fliri showed even better structural performances (Fig. 17-18): 1 linear metre of straw-bale wall, plastered on both sides, can carry 1+3+1 tonnes instead of 1+0.2+1 as according to the American construction method and structural model. Braun thinks the major static issue is not maximum admittable load, but creep control, so to keep the floors horizontal.
Also for this reason, then, structural analyses must be performed and verified for three building phases: 1) straw-bale walls only; 2) finished construction (dead load only); 3) construction in operating conditions. Rendering at the end of phase 2 stabilises the building and prevents further creep. In phase 3, live loads are taken by plaster layers.
According to Peter Braun, differential settlements of about 10 cm in straw bales are still manageable, but at Fliri's the much greater creep resulted in the risk of the ring beams not being level. Temporary loads were therefore moved on the floors to keep them horizontal as they displaced down.

Conclusions

The international repute Werner Schmidt quickly gained relies on his inherent consistency as a 'green' architect and the quality of his designs. Besides the current vogue for straw-bale buildings, it is one of his clients, Beat Küng, who best captures the key factor of Schmidt's success and uniqueness: he is able to marry competence and passion for actual building with a wide ecological vision.

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References

[1] M. Crawford, Shop Class as Soulcraft, The Penguin Press, New York, 2009

[2] A. Swentzell Steen, B. Steen, D. Bainbridge, with D. Eisenberg, *The Straw Bale House*, Chelsea Green Publishing, White River Junction, 1994

[3] C. Kohlus, interview on www.nachhaltigkeit.org (7.1.2009)

[4] G. Minke, B. Krick, Handbuch Strohballenbau. Grundlagen Konstruktion Beispiele, Ökobuch, Staufen bei Freiburg, 2009

[5] B. Berge, The Ecology of Building Materials, second ed., Architectural Press, London, 2009

[6] W.F. Smith, Foundation of Material Science and Engineering, third ed., McGrawHill, Boston, 2004

[7] T. Woolley, Natural building. A guide to materials and techniques, The Crowood Press, Ramsbury, 2006

[8] Information on http://www.bre.co.uk/greenguide/podpage.jsp?id=2126

[9] A. Nothegger, Lasttragende Strohballenbau in der Praxis, Wohnung + Gesundheit 131 (2009) 9-11

[10] B. King, Design of Straw Bale Buildings. The State of the Art, Green Building Press, San Rafael, 2006

[11] Information on www.modcell.com

[12] Conversation with Pete Walker, 29 October 2012

[13] P. Lacinski, M. Bergeron, Serious Straw Bale. A Home Construction Guide for All Climates, Chelsea Green Publishing, White River Junction, 2000

[14] B. Jones, Building with Straw Bales: A Practical Guide for the UK and Ireland, second ed., Green Books, Totnes, 2009

[15] L. Floissac, La construction en paille. Principes fondamentaux, Techniques de mises en oeuvre, Exemples de réalisations, Terre Vivante, Mens, 2012

[16] A. Bocco, Però, le balle di paglia portanti!, Il giornale dell'architettura, 98 (2011) 23

[17] Conversation with Peter Braun, 17 May 2012

[18] HTW Chur, Strohballendruckversuche, [2003] (grey literature)

[19] Information on www.fasba.de