Loam Building Techniques and Typologies in the Urban Planning Context

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Abstract

Urban development is a prime concern of the developing world. Due to limited resources and the high costs of imported materials the focus is increasingly directed on locally available materials such as loam.

Buildings of loam have been constructed in many regions worldwide ever since. The modern building context is widely detached from these old traditions and is focused on globally contemporary materials such as concrete and steel. Compared with these contemporary materials loam is inexpensive, locally available and advantageous concerning the building climate.

The aim of this paper is to introduce a catalog of housing typologies for different urban densities. These typologies are categorized based on their building structures consisting of different contemporary and alternative construction materials. Contemporary materials are represented by reinforced concrete and masonry. Alternative structures focus on loam and timber as building materials.

A table provides the planner with essential information on dimensions, material consumption and embodied energy of different building typologies and materials.

Keywords: *alternative building materials, sustainable architecture, appropriate building construction, low cost construction, loam construction, urban planning.*

1 Introduction

Building with loam has been a traditional building method within the Middle East and Africa for millenniums. It looks back on an old tradition in residential housings and urban settlements for more than 9000 years.

Currently more than half of the world's population lives in dwellings made of loam. Loam is a building material that is made by nature and easily accessible in most regions worldwide. It is inexpensive, easy to process, sustainable, fire resistant and provides a pleasant building climate.

Nowadays loam can rarely be found as a building material in contemporary constructions. Apart from a considerably large amount of small structures still being traditionally erected from loam in rural areas, loam structures only form a small niche within current state of the art projects in the urban planning context.

The present demand for environmentally neutral and sustainable building materials brings loam back to the focus of interest. A lot of specialized literature exists covering details on either contemporary or sustainable building materials. However a lack of source can be identified for a direct comparison of similar housing types of typical contemporary construction materials (e.g. concrete and steel) with sustainable natural materials (e.g. timber and loam). Such a source is essential for the planner to affirm his approach of utilizing natural materials in construction projects and shall be provided herewith.

2 Loam Building Techniques

2.1 Rammed earth techniques

The rammed earth technique is known in many regions worldwide. The technique is practiced especially in North Africa, the Middle East, Asia, Europe and Latin America. It is being applied since 7000 years as being proofed by findings.

In the rammed earth technique unconstrained moist loam is filled into a formwork by layers. Each layer has a maximum thickness of 10 cm and is compacted with a tamper. The tamper consists of a tamping plate of 50 to 150 cm^2 and has a weight of 5 to 10 kg. The fit-up formwork consists of two parallel shuttering panels. These panels are connected by spindles or threaded rods.

Rammed earth is a dry loam technique. The wall thickness varies between 40 and 90 cm.

2.2 Air-dried bricks

Common names for these earthen blocks are also "adobe" or "mud bricks". Processing the bricks can be categorized in the dry loam and the wet loam technique.

In the dry loam technique the unconstrained moist loam is poured into a mould. Then it is compressed by a manually operated or an automatic block press.

The wet loam technique is a simple technique that is used since more than 9000 years worldwide in moderate, subtropical and hot-dry climates. Mouldings of different sizes and shapes are used. The blocks are produced by manually throwing the wet loam into the forms (Minke, 2006).

Industrially processed raw loam bricks, so called "green bricks", are also commonly used. The wall thickness of loam brick walls varies between 40 and 100 cm.

2.3 "Wellerbau" technique

The "Wellerbau" technique, a wet loam technique, is suitable to erect single and two floor buildings without any formwork.

Straw and wet loam is mixed to pulp. The pulp rests for 24 hours to soak. The mass is piled up with a dung fork to wall sections of 65 to 95 cm of height adding 5 to 10 cm of surplus to the wall thickness on each side. The additional material is removed by spades creating a plane wall surface and the next segment can be added after 10 to 14 days.

The wall thickness of this technique varies between 50 and 120 cm for exterior walls and 40 and 60 cm for interior walls.

2.4 The loam loaf technique

The loam loaf technique is also known as the "Bodelschwing" technique. Wet loaves made of loam are stacked in a masonry pattern without mortar. Conical holes are made on the outer faces of the loafs by the use of a finger. This is done to provide sufficient bonding to the plaster that is applied onto the walls later. Three to five layers of loafs are laid per day.

This technique produces walls of thicknesses between 40 and 90 cm. It is often used in combination with post and beam structures.

2.5 The lightweight loam techniques

Lightweight loam is a mixture of loam and straw or cork, wooden chips, reed, foamed glass, expanded lava, expanded perlite and pumice. By this loam of a density of less than 1200 kg/m^3 can be produced, the so called lightweight loam. Light weight loam can only be implemented in combination with a primary load bearing structure like a wooden post and beam construction.

2.6 The wooden post and beam technique (wooden skeleton)

A wooden structure of posts, beams and bracings acts as the primary structure. It is erected first. Next the open segments are filled up with loam. Several methods can be applied. Common methods make use of grass mats, branches or other materials that act as a support layer in the segments. Subsequently the loam is attached manually from both sides (e.g. wattle-and-doubt technique). Since the wooden structure and the roof are erected first, sufficient weather proofing is provided to the site during the loam construction.

Within the finished walls the wooden construction is entirely covered by loam and is consequently being well preserved. The wall thickness of this technique varies between 30 and 40 cm. Due to the large consumption of timber the implementation of this technique is most appropriate in regions with sustainable forestry programs.

3 Building Physical Properties of Loam

Loam provides a pleasant building climate. Due to its ability to rapidly absorb or transpire humidity it balances the room humidity throughout the year effectively.

Compared with burned bricks loam has an equal heat conductivity but a considerably larger heat storage capacity. Loam is at the same time both an insulating and a heat storing material. Hence it has a counterbalancing effect on temperature fluctuations throughout the day (Schneider, Swimann and Bruckner, 1996).

4 Embodied Energy of Building Materials

Embodied energy is defined as the consumed energy that was used in the process of making a product. Embodied energy is an accounting methodology which aims to find the sum total of the energy necessary for an entire product lifecycle. This lifecycle includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and decomposition (Wikipedia, 2010).

Here the embodied energy shall be used as a reference value in order to compare different construction typologies of different construction materials in respect to their appropriateness (table 3). It has to be taken into account that the embodied energy of a material is subject to various factors that depend on the individual situation of the material employment.

5 Catalog of Housing Typologies and Construction Typologies

Contemporary and alternative building structures may be realized by various types of techniques according to different regional building traditions and different structural systems (as described for loam in 2). Also urban housing arrangements can consist of numerous types. Therefore the focus here shall be directed on basic and representative housing and construction material typologies for later comparison.

5.1 The housing typologies

The analysis of building typologies is based on representative residential single and two floor houses (typology 1 & 2) such as three and four floor houses (typology 3 & 4).

5.1.1 Typology 1 & 2

The selected housing typology (figure 1 left) is representative for basic dwelling houses in urban settlements. It consists of a floor plan of 4.0 by 8.0 meters and a ceiling height of 2.5 meters. The longitudinal walls are the primary load bearing members for vertical and horizontal loads. The lateral walls are supporting the lateral direction only, thus they can consist of large openings as doors and windows and provide access to the accommodation units.

Each house is designed as a single, independent unit. Within the urban context houses can be aligned in various arrangements such as detached or semi-detached houses or in different patterns of town houses (figure 2). These houses consist of either one floor (typology 1) or two floors (typology 2).

5.1.2 Typology 3 & 4

These housing typologies (figure 1 right) represent multiple dwelling units of a medium urban density. They are composed of the same basic units as Typologies 1 and 2. Here the units are combined to an apartment house consisting of two habitations per floor. The internal space linking the two apartment units on each floor provides the circulation to the apartment house. The longitudinal internal walls are penetrated by doors giving access to the apartments.

The typologies consist of floor plans of 8.0 by 10.0 meters and a ceiling height of 2.5 meters. Typology 3 and 4 represent a three and four floor apartment house respectively.

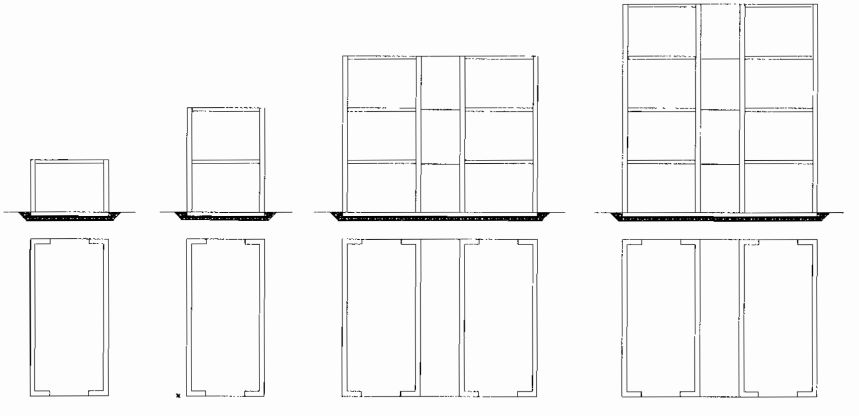

Figure 1: Housing Typologies 1 to 4.

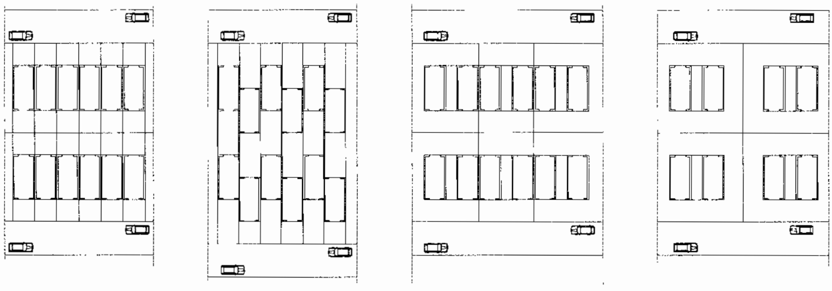

Figure 2: Examples of urban housing alignments, typologies 1 & 2 left, typologies 3 & 4 right.

5.2 The Construction Typologies

Three types of constructions are introduced for later comparison, reflecting typical structures in their respective context. One structure is mainly made of the natural material loam, one structure represents a mixed use of loam and timber and one structure consists of a load bearing structure of reinforced concrete as being widely implemented in contemporary constructions.

In the following only the primary structures (walls, slabs and respective members) are being taken into account. Doors, windows, lintels, stairs, plaster and other secondary or non structural elements are not object to the comparison.

The foundation is being considered since it represents a recognizable amount of concrete. A reinforced slab foundation of 20 cm is used for typologies 1 and 2 and of 30 cm for typologies 3 and 4.

Table 1: Typology data and notations.

	Typology 1	**Typology 2**	**Typology 3**	**Typology 4**
Floors	1	2	3	4
Length x Width x Height [m]	8 x 4 x 2.5	8 x 4 x 5	10 x 8 x 7.5	4 x 8 x 10
Accomm. Units	1	2	6	8
Reinforced Concrete	***RC1***	***RC2***	***RC3***	***RC4***
Loam	***L1***	***L2***	***L3***	***L4***
Loam & Timber	***LT1***	***LT2***	***LT3***	***LT4***

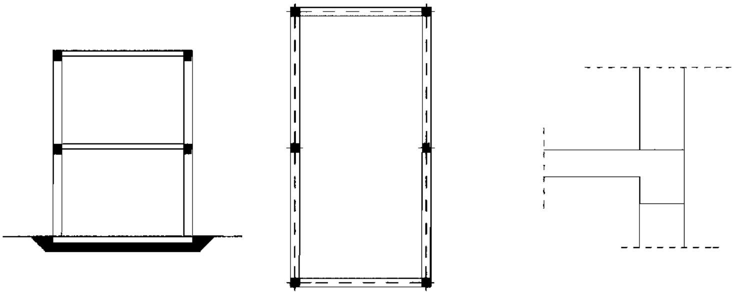

Figure 3: Reinforced concrete construction, 2 floors - *RC2,* section, floor plan and detail.

5.2.1 Reinforced concrete and masonry construction *(Type RC1 – RC4)*

The reinforced concrete frame structure is composed of six concrete columns, 25 cm by 25 cm (every 4.0 m) and beams of 25 cm by 30 cm. This frame structure acts as the primary load bearing structure for both vertical and lateral loads. The non load bearing walls consist of masonry of 20 cm thickness of either bricks of hollow blocks. The reinforced concrete slab has a thickness of 15 cm.

The roof is realized as a flat roof with no or just minor overhang as a concrete slab with 5 cm of screed and waterproofing.

Such kind of structure is representative for contemporary engineering designs for structures of urban dwellings in many African countries and large parts of the Middle East.

5.2.2 Loam construction *(Type L1 – L4)*

The selection of the loam structure is based on a maximum employment of loam as a construction material. Constructions consuming a large amount of timber as load bearing elements of the vertical structure (e.g. wooden post structures) do not represent the situation of the natural supply in Sub-saharan and Northern Africa such as the Middle East appropriately.

The structure consists of load bearing walls of an average thickness of 45 cm (due to load bearing such as climatic reasons). The short, lateral walls may be penetrated by larger openings for the circulation of the building. The walls are composed of solid loam and are either constructed by rammed earth, loam bricks or the loam loaf technique (description of techniques see 2.1 - 2.4). By each of these techniques the loam is compacted by a ratio of approx. 1 : 1.3. The maximum ceiling height of each floor is 250 cm.

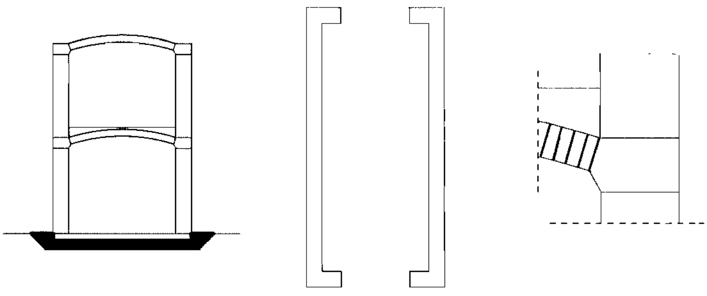

Figure 4: Loam construction, 2 floors - *L2,* section, floor plan and detail.

The slab is made of a barrel vault structure of dried loam bricks (with a rise of 30 cm). The construction of the vault requires a re-usable formwork or gage. The slab is filled up with loam from the top. The total slab height amounts 55 cm.

A ring beam of steel reinforced concrete of a height of 30 cm is located on top of the loam walls. It is providing support to the vault slab structure and acts as a load distributing member. The ring beam is supported by laterally oriented horizontal tie members of steel to couple the horizontal loads resulting from the vault.

The roof is constructed by the same principle as the slab. In addition it is covered by a layer of reinforced screed and water proofing. Sufficient roof overhang and drainage is to be provided to the structure to ensure sufficient protection from rain water. This is realized by cantilevers of 1.5 m of the ring beam along the lateral (short) edges. Any free standing longitudinal wall has to be protected by appropriate measures.

5.2.3 Loam and timber construction *(Type LT1 – LT4)*

Many areas of urban development are located in seismic zones. Hence a third type of construction is being introduced possessing a higher safety in case of an earthquake.

This construction consumes smaller amounts of loam and concrete since both ring beam and slab are constructed from timber. Timber or bamboo here is an essential additional construction material to enhance the resistance of the system.

The structural principle is based on a redundant system of the vertical load path. On the exterior and within the long walls additional wooden columns are being located. The wooden structure of the roof and the ring beam supporting

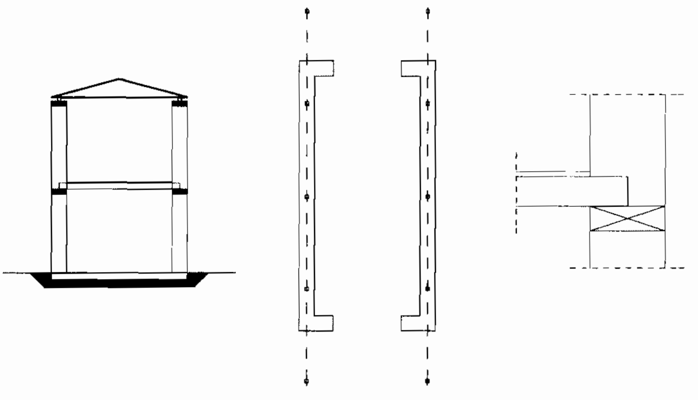

Figure 5: Loam and timber construction, 2 floors - *LT2*, section, floor plan and detail.

the slab are connected to these columns. They are vertically supported by the longitudinal loam walls at rest. In case of a local failure of a portion of a wall segment the ring beam acts as a beam, transmitting the load of the slab to the wooden columns.

A particular structural analysis of this type of structure and its resistance towards seismic actions is not object of this investigation.

6 Compilation of Data of the Different Typologies

In order to evaluate and compare the different housing and construction typologies according to different criteria it is essential to compile relevant construction data. Table 3 provides data on building dimensions, material consumption and embodied energy. To have a common ground of comparison the data on material and energy consumption is determined per square meter living area.

Material prices and the processing of materials during the construction depend on the particular time and the local context. The embodied energy is a material immanent value (as described in 4). Hence it is listed here as a reference value.

The determination of the material consumption is based on the specifications of dimensions given in the description of the different typologies (5.1 and 5.2).

The determination of the embodied energy per square meter living area is based on the data of embodied energies in building materials (Landesinstitut fur Bauwesen und angewandte Bauschadensforschung NRW, 1993).

Table 2: Embodied energies of materials.

material	embodied energy [kWh/m³]
Loam	10
Timber (soft wood)	470
Bricks	1360
Concrete	3200
Steel	70000

Table 3: Construction data of typologies

type		building data				material consumption					energy
		accomm. units	covered area	living area	built volume	concrete	bricks	steel (reinf.)	loam	timber	embodied energy
						[material volume or weight per living area]					[energy per living area]
			[m²]	[m²]	[m³]	[m³/m²]	[m³/m²]	[kg/m²]	[m³/m²]	[m³/m²]	[kWh/m²]
concrete	*RC 1*	1	32	26	86	0.58	0.26	59			2717
	RC 2	2	32	53	166	0.41	0.26	42			2057
	RC 3	6	80	158	616	0.47	0.26	48			2299
	RC 4	8	80	210	816	0.43	0.26	44			2111
loam	*L 1*	1	32	22	86	0.44		45	1.21		1819
	L 2	2	32	44	166	0.28		28	1.23		1156
	L 3	6	80	132	616	0.31		32	1.31		1284
	L 4	8	80	176	816	0.26		27	1.32		1087
loam & timber	*LT 1*	1	32	22	86	0.29		30	0.87	0.14	1270
	LT 2	2	32	44	166	0.15		15	0.87	0.12	664
	LT 3	6	80	132	616	0.18		19	0.87	0.12	814
	LT 4	8	80	176	816	0.14		14	0.87	0.12	626

7 Discussion of Results

Material prices depend on the particular time of their employment on the site such as the local context as infrastructure, availability and processing. Hence material prices are not used as a comparison value in table 3.

Prices can be calculated by the planner according to the information on material consumption that is based on the specifications given in the description of the different typologies (5.1 and 5.2) as well as appropriate cross sections and amounts of steel reinforcement of structural members of these types.

According to the living area provided by the different construction typologies, typologies *RC1* to *RC4* (reinforced concrete and masonry) show the most effective exploitation. Compared to structures of loam, the dimensions of the walls of these types are thinner. This is advantageous concerning the internal space. Concerning the building climate on the other hand the loam based constructions have a considerable advantage especially in regions with high temperature fluctuations throughout the day (see 3).

Taking the embodied energy per square meter living area as a comparison value it can be observed that in general the housing typologies with two or four floors show the lowest amounts. This is due to the equally considered slab foundations for housing typologies 1 and 2 such as for housing typologies 3 and 4 respectively. Thus the gained living area by typologies 2 and 4 reduce the amount of embodied energy per living area in comparison to typologies 1 and 3 respectively.

Lowest consumptions of embodied energy per square meter living area can be found for the loam and timber constructions. Here the ring beam is made of timber instead of a reinforced concrete member. Since both concrete and steel hold the highest values of embodied energy the impact of that replacement can be seen from the results.

8 Conclusion

In general it can be stated, that for different urban housing typologies the consumption of the embodied energy can be reduced to approximately 50% by employing sustainable materials as loam and timber. Additionally the utilization of these materials in comparison to concrete and masonry is considerably more cost effective.

An appropriate solution of building construction depends to a high extend on local factors like availability of materials, infrastructure and costs.

Timber is appropriate as a building material especially in regions with sustainable forestry programs.

Steel reinforced concrete and brick constructions are currently widely used in construction projects. Apart from holding the highest values of embodied energy, these materials are not locally produced everywhere.

Loam on the other hand is available in almost any region worldwide. Although the employment of loam results in a relatively high construction volume it is cost effective, beneficiary concerning the energy consumption and advantageous to the building climate. Hence loam is a serious alternative construction material for different housing typologies in the urban planning context.

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