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LINNIG
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Earthquake risks?
More safety with timber constructions!

HOLZABSATZFONDS
GERMAN TIMBER PROMOTION FUND

Iran – a tectonical collapsible region

Iran belongs to an earthquake zone reaching from Portugal to the Himalayas. This zone lies on three earth crust plates which slowly move from the south and collide with the large fixed Eurasion landmass. In the west of the zone the African plate presses against Europe, in the east the Indian subcontinent runs into Eurasia.

The collision of the plates leads to a compression of the earth's crust, leading to faults and displacements. Within these tectonical regions so called fold mountains can arise like the Zagros mountains in the west and south of Iran. Collisions at these geologically new fold mountains cause earthquakes, these originate from deep below the surface – the so called hypo-centre.

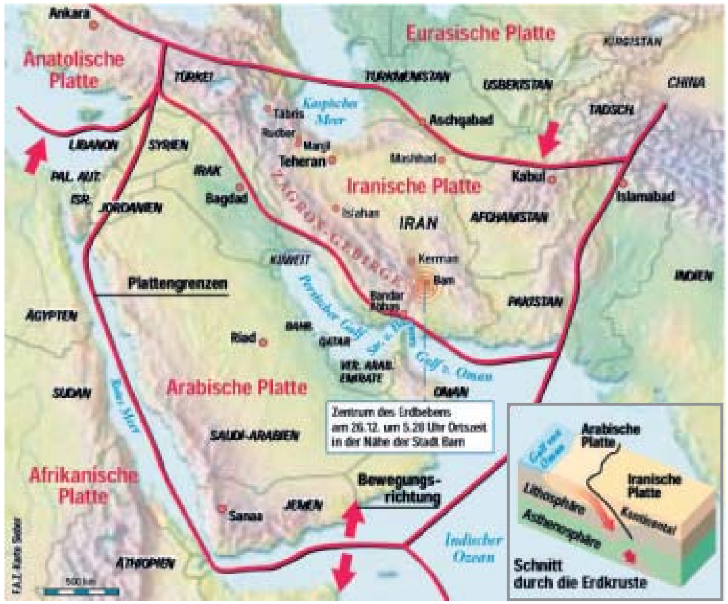
The ground shakes – buildings under earthquake impact

Beneath vertical acceleration and cracks in the earth's surface horizontal accelerations are the greatest danger for buildings. The dynamic forces in a structure mainly depends on the following conditions:

- earthquake intensity (resulting ground movement)
- site conditions (ground-structure, interaction and composition, soft or hard ground)

These conditions are given and cannot be influenced unlike:

- the floor plan / bracing concept
- building height
- structural form
- choice of building material
- mass and stiffness distribution
- ductility of the structure

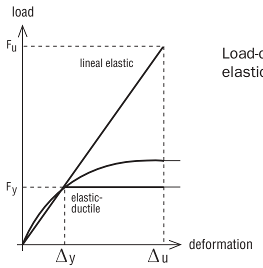


Along the Persian gulf the Arabic earth crust plate slowly slides under the Irani plate.

Wood is light

Wood has a better proportion of strength to dead load than other construction materials. The light weight of wood-frame buildings causes smaller inertia forces and results in a comparatively smaller design loads.

Wood houses are tough



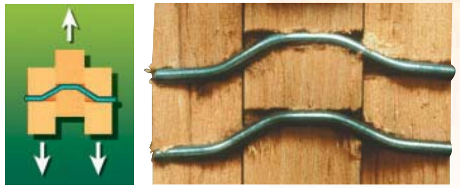
Load-deformation relation of elastic and ductile structures

The toughness of the structure – the so called ductility (non-linear deformation capacity) – improves the load bearing performance of timber structures under earthquake loading. The ductile deformation capacity helps the structure to dissipate energy.

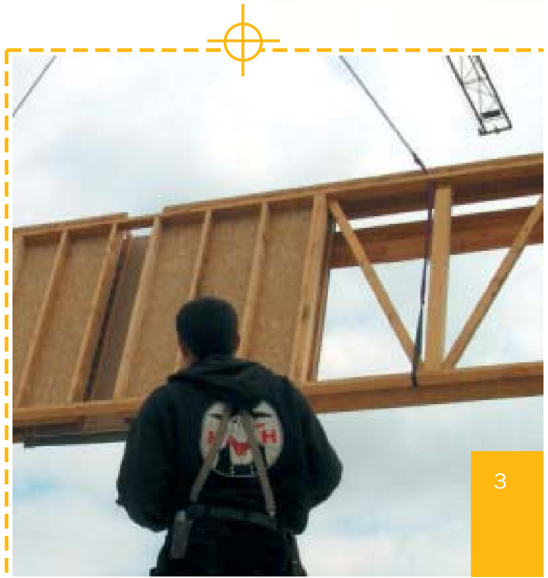
Wood as a building material does not have large ductile capacities, except for a small capacity under pressure perpendicular to the grain. Timber constructions create ductile chains through their joints. Relatively rigid construction elements are connected to areas with ductile capacity. The ductile bearing is achieved by mechanical joints such as nails, screws and bolts.

ductile chain

An appropriate design of the joints guarantees a combined elastic and plastic deformation of the structure.



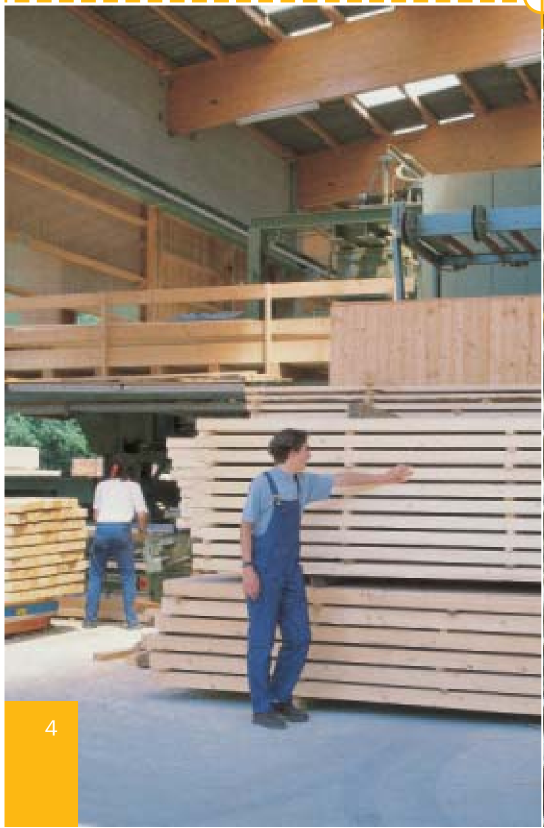
The plastic deformation results from the ductile behaviour of the fasteners and the local plastification of the wood.

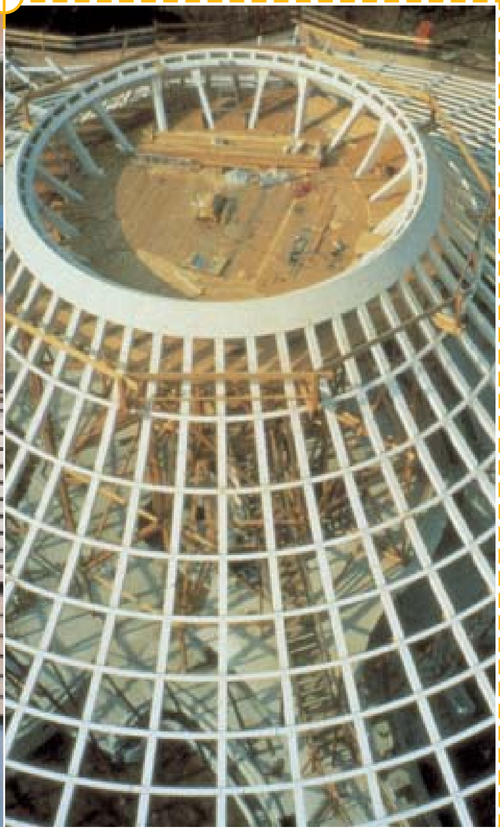


Timber - the future's resource

Wood has always been one of the most important building materials and the basis for many daily used products. It is naturally renewable, easy to obtain, to handle and to transport, as well as resistant and dimensionally stable but at the same time elastic and comparatively light in weight. Furthermore timber is the right product for the environment because of sustainable forestry.

In the long tradition of craftsmanship sophisticated techniques for treatment and processing for different types of wood have been developed. As a building material timber offers today almost unlimited construction possibilities and offers advantages compared to the other materials regarding its load-bearing capacity, durability and economic efficiency.





Building with timber in the past ...

From the beginning of civilisation until the industrial century wood has played an important role in man dealing with his environment. By using wood – the oldest of all building materials – a construction method was developed that became the base for all later constructions methods. Throughout time the knowledge of timber constructions was spread all over the world and developed in all cultures and civilisations ignoring all geographical boundaries. Wood as a building material could answer almost every demand – no other material could and can be applied in so many different ways. The application of wood was not only restricted to Central Europe but was also to be found in designated earthquake regions. This is proved with multi-story buildings in Istanbul from the 17th century and the Japanese temples.

Historical timber houses in Istanbul. The buildings which are up to five stories high withstood for decades all earthquakes due to their basic ductile construction.

Pagoda of the Yakushiji-temple – founded in the year 680 near Nara, Japan.

... and today

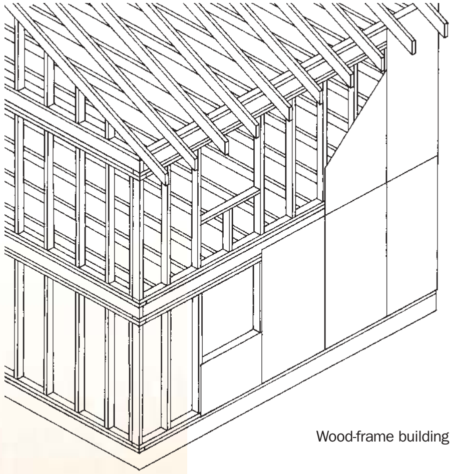
Timber bridge

Today's timber constructions combine the traditional craftsmanship with industrial high-quality production methods. Due to modern processing and joining techniques the properties of the raw material wood can be utilised more efficiently. By extensive research not only the use of solid timber has been improved but many new high-capacity timber and timber-based materials have become available.

The performance abilities of timber constructions are not only documented by technically demanding structures such as bridges and wide-spanned halls, but also by many earthquake safe buildings.

To build an earthquake-resistant timber structure does not require a large amount of material, but the accurate planning of important connection details. The great advantage is the cost efficiency.

The system: wood-frame building method



Wood-frame building

The modern wood-frame building method, that evolved more than 100 years ago from the traditional timber-frame construction method, has incorporated the use of newly developed sheathing panels. In the building components for walls, ceilings and roofs single solid elements take over the vertical load whereas the sheathing panels reinforce and brace the elements as well as the entire construction.

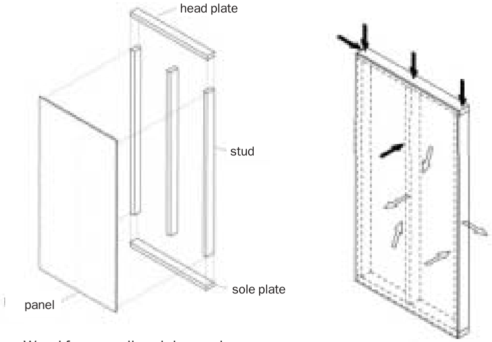
The flexible composition of the single components allows an architectural open system without limitations. The hollow spaces in between the posts can be filled with insulation. The load bearing construction, the insulation and all other physical building layers are combined in one multifunctional building element.

The spacing of posts, rafters or ceiling joists for a covered wood construction result from the measurements of derived timber product panels.

The wood-frame building construction has been considerably improved over the past decades. The development of highly resistant materials has played an important role in improving the quality of timber engineering. The recoverability and durability of houses built with wood are equal to those of regular constructions built with brick or concrete. They have proven to be solid, economical and flexible.

The capability of the system is not limited to two storey houses. Appropriate planning, design and execution also allows the construction of multi-storey housing such as administrative and industrial buildings.

Structure



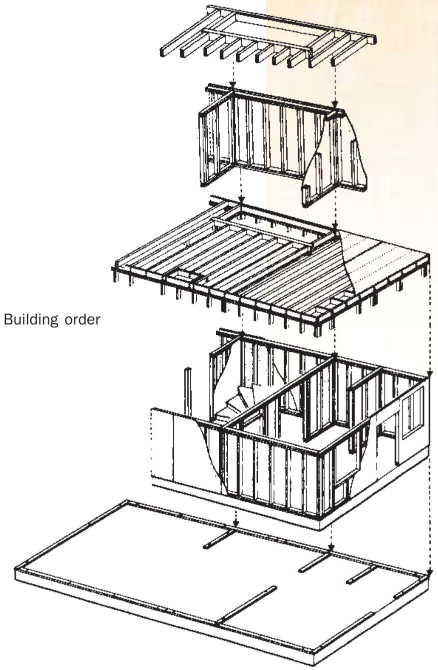
Wood-frame wall and demands

Together the posts and panels create a system, which is capable to carry a multiple load - more than the sum of the capacity of the single units. The panel prevents the posts from buckling sidewise whereas the posts prevent the panels from buckling outwards. The joining of the panels on the posts is done using mechanical fasteners such as nails, staples and screws. The building elements for walls, ceiling and roof units can be built on site as well as for prefabrication of complete building units.

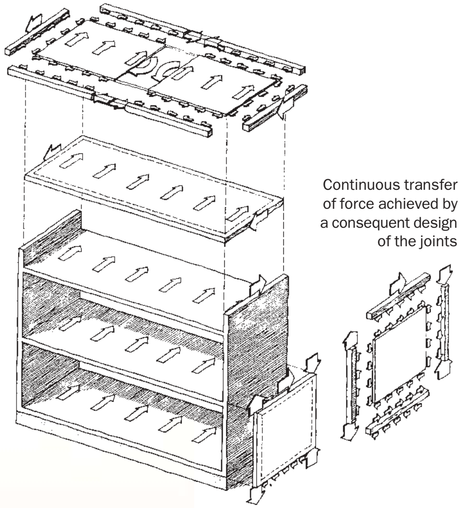
Fabrication

1. After completing the foundation the sole plates are fixed to the foundation using anchor bolts.
2. The wall elements are joined to the sole plates.
3. In the next step the ceiling elements or single beams are fitted. Sheathing panels provide the diaphragm-function. Every finished storey serves as a platform for the erection of the next storey.
4. After the completing of the roof the interior and installation work follows.

Building order



Wood-frame buildings under earthquake load



Continuous transfer of force achieved by a consequent design of the joints

The earthquake movements cause inertia loads which magnitude depends amongst others on the moving mass. In most cases, only horizontal inertia loads are relevant for the design.

Force distribution

Crucial for earthquake safety is an easy and preferably direct distribution of force through the single elements of the structure to the foundation.

The ductile character of shear walls and floor diaphragms is thereby of great importance. The elements are designed to have the required strength and stiffness to carry all loads including those caused by earthquakes. At the same time the toughness of the joints is used in order to dissipate energy in case of a strong earthquake.

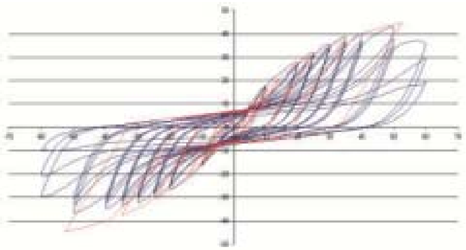
The roof and floor diaphragms, in which typically the horizontal forces are concentrated, transmit seismic forces to shear walls acting as lateral-forces-resisting elements at each storey level.

The lateral forces to be resisted are summed sequentially to the lower floors. The largest resisting force, which acts at the lowest level of the building in the interface between the shear wall and the foundation, is known as the base shear.

Shear walls and diaphragms

Installing wood structural panels to create shear walls and horizontal diaphragms is the best-known way to strengthen wood-frame buildings.

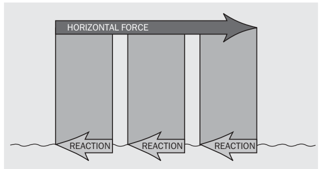
They maintain high strength in the design range and, if pushed to their ultimate capacity, yield gradually while continuing to carry load. Therefore the structure does not fail brittle and spontaneously. Overstressing causes the ductile deformations without an overall collapse of the structure. In case of an earthquake this response is the most important quality of a building for human safety.



Load-deformation of a shear wall under cyclic loading

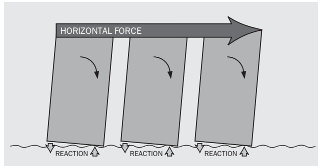
Anchoring systems of shear walls

The sill plates of the shear walls are fastened to the foundations at regular intervals with anchor bolts in order to transfer the horizontal force.



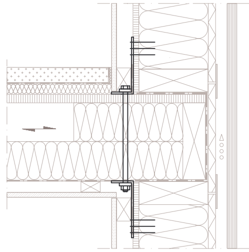
Base shear

When an object is bolted down – restrained from sliding – and a lateral force is applied, an overturning moment develops causing overturning forces.

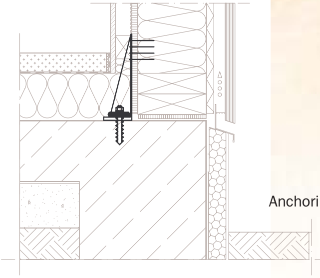


Overturning forces (compression and tensile forces)

This overturning forces must be resisted by the use of connectors, called hold-down anchors, installed at both end studs of each shear wall. The top of a shear wall is fastened to the second floor or roof framing and the bottom is fastened to the foundation.



Floor joint



Anchoring to foundation

Wood frame construction in combination with clay

Iran has a long tradition in building with clay. Constructions built with clay bricks have lasted for centuries indicating that clay if professionally used, can be extremely long lasting.

The Bam earthquake has disputed the easy and cheap available building material clay. Nevertheless its great advantages cannot be denied.

The bearing structure is physically completed by the clay filling. By its ability to absorb and evaporate humidity, houses built with clay are characterized by their comfortable indoor climate. Clay is able to store and insulate heat, that is why it equalizes changes in temperature well. Additionally wood is preserved by clay due to its capillary conductance. Hence timber and clay perfectly complement one another.

Material and transport costs can be minimized by using the local available clay bricks. The great knowledge of handling and fabrication of clay bricks should be used. The input of machines is comparatively small.


Wood frame walls before infilling


Wood frame walls filled in by clay bricks

Wood building products

Sawn soft-wood (from spruce, pine) is a high performance building material and the main basis for building timber structures. Compared to other building materials wood products have a high strength and are easy to handle and machine. For highly stressed structural elements high performance timber-based building products are available.

Structural sawn timber products are upgraded solid timber derived from spruce, fir, pine or larch. By selective choice of sections and kiln-drying, the timber is dimensionally stable and cracking is reduced. Because the timber is planed and bevelled, the high quality surfaces are appropriate also for using in uncovered construction. Kiln-dried sawn timber is available in thicknesses of up to 120 mm and heights of up to 240 mm. The maximum available length is 14 meters.


Solid structural timber (KVH®)

Glulam timber

Glulam is an engineered wood product manufactured by gluing together dried lumber laminations with a waterproof adhesive. Beforehand the wood is dried and visually and mechanically sorted for strength and stiffness. The result is an improved and dimensionally stable product, that can be produced in any dimension. It is particularly suitable for wide spanned or highly stressed structural elements that have to be at the same time optically appealing or dimensionally stable (little deflexion).

Structural wood based products are manufactured from different sized wood extractives such as fibres, particles, veneers, boards by pressing and gluing them together with adhesives or cement. Strength reducing effects like knotholes and cracks are minimized. Wood based materials can be machined like usual lumber. Using wood based materials in their standard dimensions has positive economic effects on planning, storage, fabrication and construction time.


Plywood panels are built-up from sheets of softwood veneer glued together with a waterproof adhesive. The grain direction of each sheet is alternated.

Fibreboards are built-up from lignified fibres pressed together partly with added adhesives.

Oriented strandboards (OSB) are structural panels made from thin, short wafers located in the outer layers and oriented in the long direction of the panel.