Dawn of a New Era – World First Timber-Built Car Park

Martin Zaugg
Zaugg AG
Rohrbach, Suisse

Project name	Timber-Built Car Park
Project location	2557 Studen, Switzerland
Author	Stephan Zaugg, CEO/Owner, M Civil Eng ETH/SIA, MBA
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1. Starting point and brief

COTRA Autotransport is an independent specialist in automotive transport and logistics. It has an annual transport volume of 150,000 - 200,000 vehicles. The company provides major auto-importers with handling centres for processing newly imported vehicles from coordination with the manufacturer through customs, warehouse management, cleaning and quality control to ensuring the vehicle is visually and mechanically sound. It also offers a fleet management service with central processing and maintenance of used vehicles and storage space for all types of vehicle.

Major investors have invested in vehicle processing at the processing centre in Studen. The planned expansion of services for new and used vehicles now required additional parking and holding capacity.

Additional parking space for 1,600 vehicles as well as a further 200 holding bays for vehicles awaiting loading onto auto-transporters was required at the existing site. The new spaces also had to comply with its new logistics concept (shortest possible travelling distances). The obvious solution therefore was to go upwards.

The existing vehicle stall dimensions of width 2.55m, length 5.00m and with carriageway aisles of width 5.00m had proven fit for purpose and were the template for the new areas. However, for the desired 1,800 new stalls alone (without access roads or carriageway aisles) this meant an additional net area of around 23,000m2!

2. Foundation problem

During the feasibility study the planners quickly became aware of the foundation problem. The site lies in the immediate vicinity of the old Aare River, which was drained 150 years previously in what is known as the Jura Water Correction project. The admissible ground pressure is quite low at 200kN/m2. The ground water table is between -1.00m and -1.50m and any foundation works must take this into account accordingly.

Not least on cost grounds it was decided very early on to forgo expensive foundations in the ground water or use of pilings in favour of a solution using flat foundations.

3. Evaluation

The maximum fire area of 9,600m2 per storey as well as the maximum escape distance of 35m was a limiting factor for all variants, irrespective of the construction.
In the feasibility study the different options with respect to building width, building length and the number of storeys were compared with what was technically possible in terms of processes and construction types, surfaces and laminations. The maximum building height of 18m according to the local building regulations could not be fully exploited with any variant:

- For weight reasons, a solid concrete construction offered a very poor ratio of foundation dimensions to possible number of stories.
- A steel construction could only be implemented as a hybrid structure with steel-reinforced concrete slabs (e.g. Holorib) and faced the same weight problem as a solid concrete construction or one with timber slab elements.

Solid constructions (concrete) and steel construction with concrete hybrid slabs were therefore ruled out because of the minimal floor pressure allowance and inherent weight of the components. These variants could not offer adequate use of the available space.

The most favourable design variant was found to be a three-storey lightweight construction; additional storeys would have required expensive foundation work to comply with the ground requirements.
However, the 1,800 additional parking spaces needed could not be achieved with three storeys and maximum fire compartment areas of 9,600 m2. For reasons of fire-safety, site specifics and economy it was finally decided to create not one, but two three-storey car parks with one central access and exit:

- South car park: three storeys, footprint 51m x 165m, with a total of 1,182 parking spaces (in construction)
- North car park: three storeys, footprint 51m x 135m, with a total of 960 parking spaces (planned)

The timber-orientated design team then asked the question of whether an all-timber construction would be a feasible and perhaps even economical alternative to the timber and steel hybrid construction?
The answer was yes: by cleverly combining the experiences of multi-storey timber construction with the experience from timber bridge construction an extremely well-thought out timber construction was developed. The client accepted this design despite (or because of) the fact that no other similar-sized building had ever been built anywhere in the world.

Swiss fire safety regulations allow a fire compartment area per storey of maximum 9,600m2 for partially open (exterior walls with at least 25% non-closing openings) single or multi-storey car parks. The fire resistance requirements of the support structure depend on the building height. Up to a total height of 11m the requirement is R 30 and up to a total height of 30m it is R 60.
If the exterior walls have at least 25% non-closing openings, components of the construction which comply with RF1 (e.g. steel), do not need to meet the requirements for the fire resistance of load-bearing components in areas within 35 m of a non-closing opening.

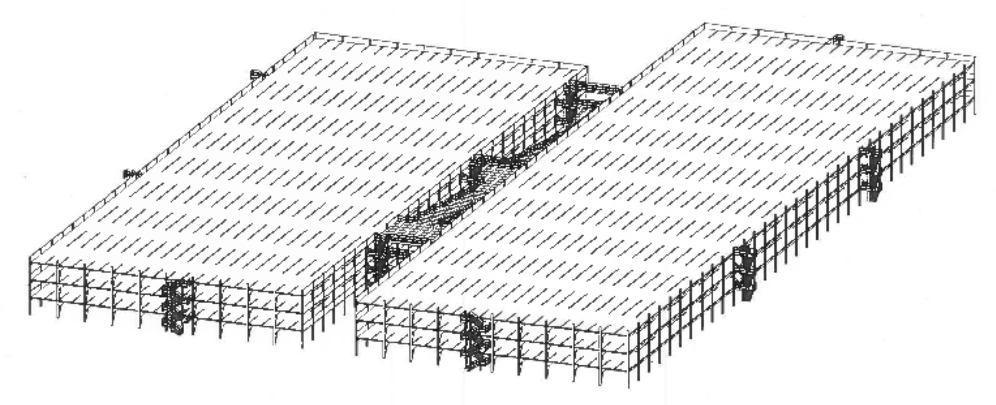

Figure: 1: Axonometric view from the planning application

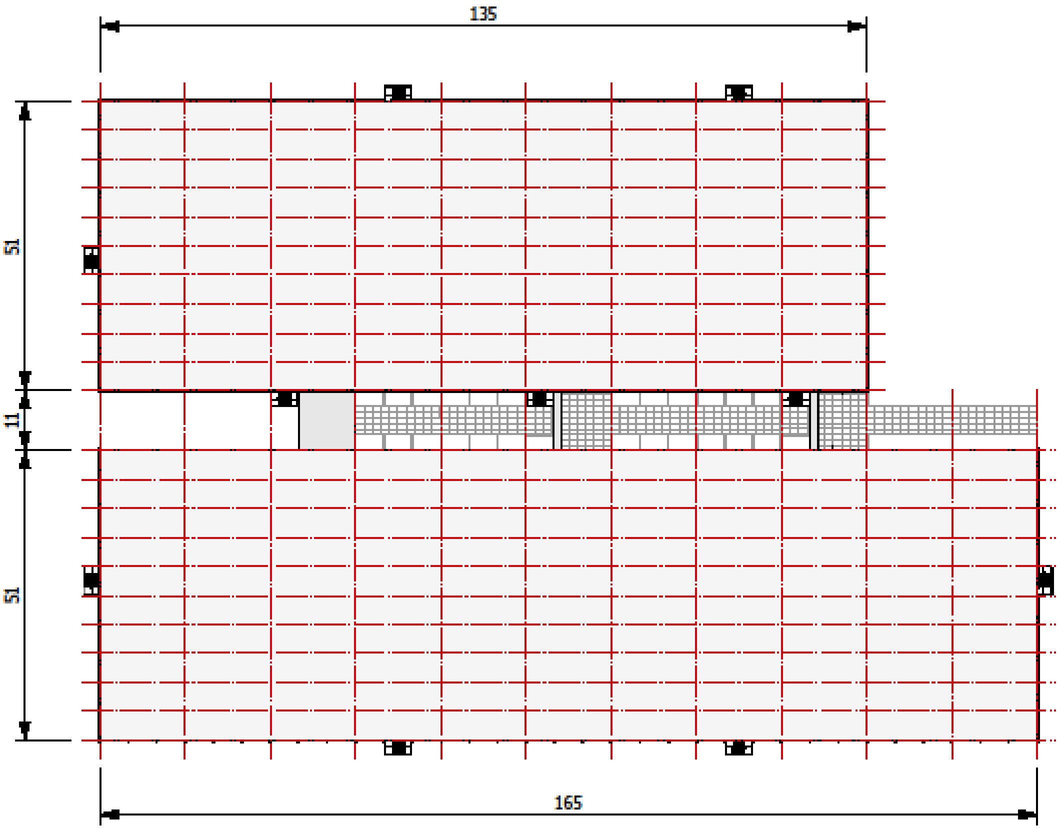

Figure 2: Plan view from the planning application

4. Basic concept

The car park is a modular structure. It has an unsupported longitudinal grid of 15m (5m stall + aisle width 5m + 5m stall) and a latitudinal grid of 5.1m (2 stalls, dimensions 2.55m) which can be combined as required. The 5.1m x 15m support grid permits problem-free parking and exit without interference from pillars in the stall. The minimum room height was set at 2.15m.

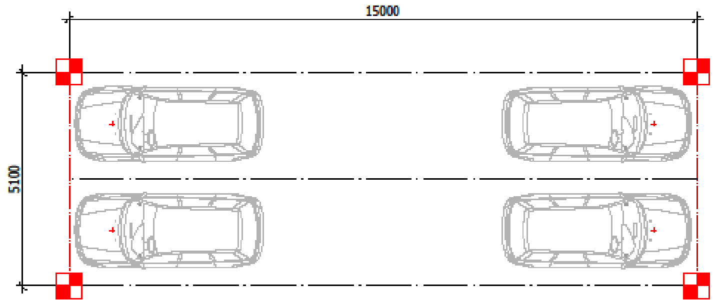

Figure 3: Stall grid

There is no minimum or maximum size for this modular car park. The maximum size is defined only by the available space and the fire safety requirements.
The exterior walls are left substantially open. The only precaution is a planned weather-exposed wind break screen.
The inter-storey slabs consist of five-ply cross-laminated timber as the carriageway slab, which also acts as the fire compartment-forming element. The slabs are covered with two layers of mastic asphalt (30mm + 25mm) with a separation layer and sealing membrane. A 2% pitch towards the outer edge of each of the inter-storey slabs allows water to flow off. The access ramp, façade pillars and stair towers are made of hot-dip galvanised steel. The timber is not therefore exposed to weather or moisture which means that the structural protection of the timber is entirely sufficient to guarantee a long service life of the supporting structure.

5. Structural concept

5.1. Vertical load transfer

The secondary support structure in the form of a multi-span five-ply cross-laminated timber has a span width of 5.1m. The panel is 140mm thick with an element width of 2.5m and also acts as the carriageway. The 200/960mm slab joists are coupled multi-span elements with a distance between axes of 5.1m and respective span width of 15m. The individual 15m modules can be connected together in any configuration with articulated joints.
The strength class of the slab joists vary depending on application (e.g. boundary elements). The structure incorporates GL24h, GL28k and GL32k slab joists which rest on V-formed pillars. This pillar arrangement allowed the span width to be reduced and enabled optimum preconditions to be created for horizontal force dispersion. The floor, with offsets for the struts, is made of BauBuche GL70. The struts are made of laminated timber GL24h with offset geometry determining their varied cross sections of up to 200/360mm. The support load is then transferred via end-grain contact to the vertical pillars and on to the strip foundation, which is designed with a maximum foundation width of 2.5m.
Particular attention was paid to the vibration behaviour of the carriageway aisle and the primary supporting structure. The problem in this regard was that no timber-built car park of any considerable size had ever been built and so there was no available standard practice, reference information or experience of colleagues.
Useful information was gained from a public car park in Innsbruck built 10 years previously with a steel support structure, but which also incorporated cross laminated timber panels and a mastic asphalt overlay. A walk around the site reported the vibration behaviour subjectively as "pleasant" and "comfortable". The existing hybrid construction was then recalculated and compared with the project in hand to obtain as realistic a comparison as

possible (focus - vibration damping). Finally, the theoretical values of a filled car park (maximum payload according to standard), of normal use with empty aisle and of the empty state were simulated and the technical design was calibrated correspondingly.
It is planned to take vibration measurements from the completed car park in order to compare actual results with the calculated values.

5.2. Horizontal stiffening

The horizontal loads on which the decisions were based were taken from an "earthquake" load scenario. The aisle slabs on all storeys are formed as shear panel. The V-form pillars absorb the loads in the longitudinal direction.
Horizontal stiffening in the transverse direction is created by wind bracing made of ASDO tie bars. To absorb the vertical load elements resulting from the cross-ties in addition to the existing vertical loads, the pillars for the wind bracing are made of BauBuche GL70 instead of GL24h.

6. Constructive design and assembly

Ease of assembly was a top priority from the start of the project. The constructive details had to be simple, repetitive and fast to assemble.
The V-shaped pillars were attached to the floor and assembled in our factory. We also produced the steel components as well as the entire steel ramp. The aisle slabs and slab joists were bonded directly by the glue shop according to a precise logistics schedule and delivered "just in time" to the construction site.
Assembly was vertical, i.e. for each segment all three storeys were fitted and sealed simultaneously. The hoisting gear was then manoeuvred to the next point and the whole process repeated again. Occupational safety was a high priority: the railings were bolted on before installation of the carriageway slab, for example.

Figure 4: The dimensions of the 5.1m x 15m support grid together with the clearance between the slab joists give a pleasant feeling of space.

Figure 5: The V-form pillars with the BauBuche floor and lateral consolidation poles for absorption of the loads from the storeys above were assembled in the factory. The varying strut dimensions result from the different forces in the boundary elements; the different heights are due to the pitch of the carriageway aisle.

Figure 6: V-form pillars after assembly. The transfer of vertical forces from the upper storeys, from the slab joist, and the transfer of the horizontal forces in the longitudinal and transverse directions at the same point makes this the node point of the car park in the most literal sense of the word.

Figure 7: The steel facade pillars can be seen to the left in the picture. All other components are protected from weathering and are made of wood.

Figure 8: Assembly takes place segment-by-segment across all three storeys. The separation layer and the sealing membrane are fitted immediately after the installation of the carriageway slab.

Figure 9: Assembly takes place segment-by-segment across all three storeys. Guardrail are assuring the safety on site.

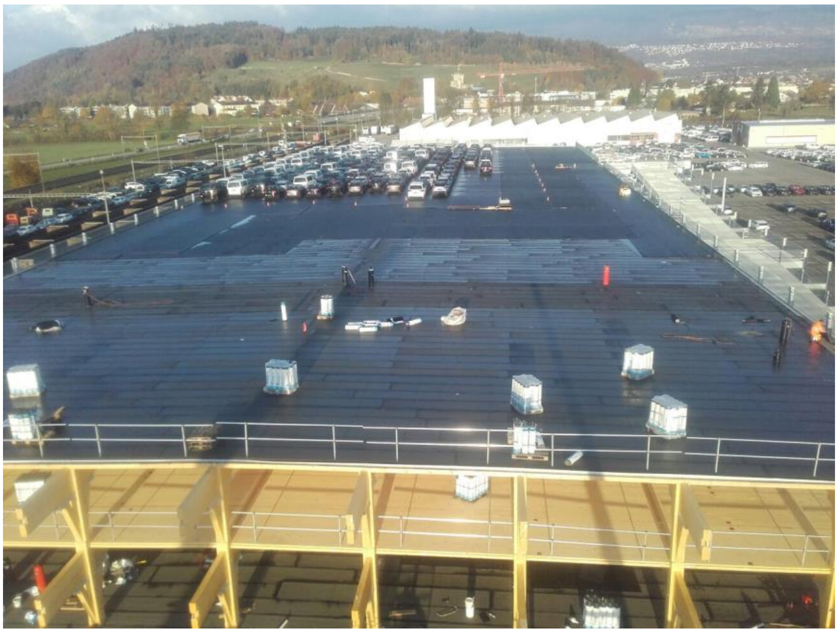

Figure 10: The clients already needs space on the top floor, although construction is still under way.

Figure 11: In order to assure the construction progress, the ramp was the first element at the beginning of the works on site.

Figure 12: The ramp assures the access of secondary work such as the mastic asphalt.

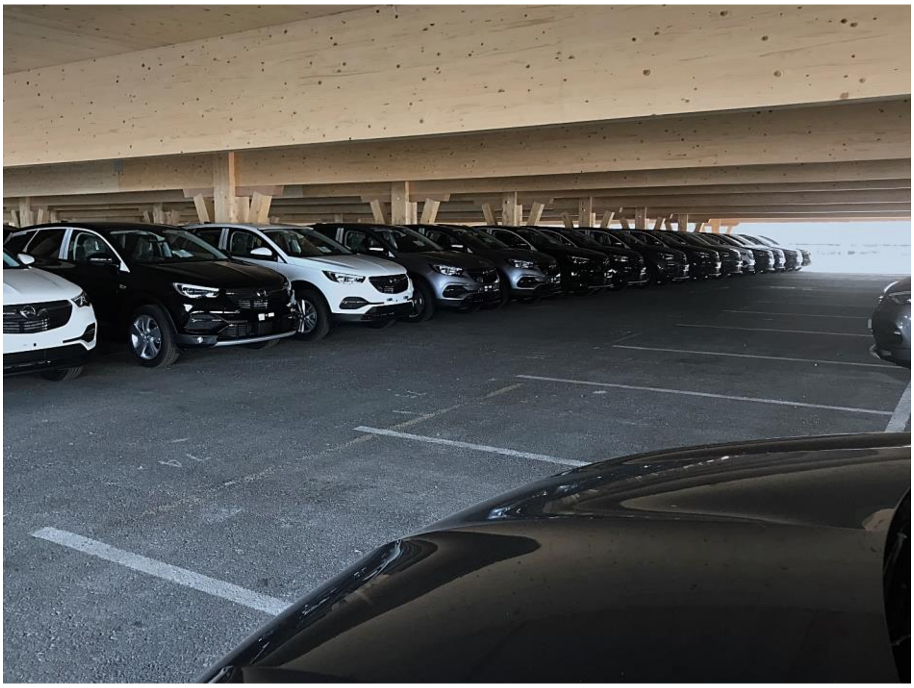

Figure 13: Parking situation during construction phase on ground floor

This design not only represents a completely new development in timber construction, the car park is also aesthetically pleasing and is extremely well received by the customers. The client must be thanked for being consistently open to innovation and for being an outstanding working partner throughout the project.

Facts about the south car park

Total car parking spaces	1200 (phase 1: 2017, finished in December 2017) 984 (phase 2. 2018)
Total area for 3 storeys:	25,245m2 (or 271,735 sqf)
Laminated timber (various strength classes):	1,100m3
BauBuche GL70:	30m3
Cross-laminated timber panels:	3,400m3
Steel: (incl. ramp)	220t
Client:	COTRA Autotransport AG. 5242 Lupfig
Architecture:	Zaugg bauconcept AG, 4938 Rohrbach
Structural engineering for timber and steel construction	Zaugg AG Rohrbach, 4938 Rohrbach
Timber construction:	Zaugg AG Rohrbach, 4938 Rohrbach
Steel construction:	Zaugg AG Rohrbach, 4938 Rohrbach

Author: Zaugg AG Rohrbach, Stephan Zaugg, CEO/Owner, M Civil Eng ETH/SIA, MBA