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Towards a Geometry-Oriented Construction Process in Structural Engineering

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On the Role of Surveying during Construction of Buildings

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Object of Discussion here: Typical Office Buildings

i.e. several levels,
no specific architectural requirements

Large Buildings: Involve an expert from Surveying Engineering (internal or external)

Smaler Buildings: Surveying by civil engineer or technician or handcraft man

Tasks for Surveying Profession during Construction of Office -Buildings

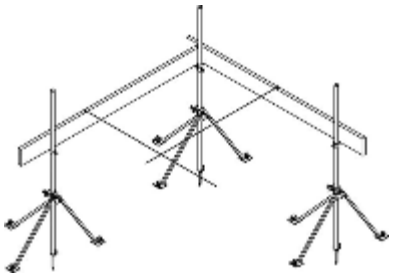
- Positioning of building within official state coordinate system
- Determination of height level of relevant points for foundation and in different levels
- Setting-Out of principal axis for groundlevel of building, represented by a few main points (physically defined marks)

Sometimes:

- Support for alignement stage (if any)
- Setting-Out for main installations (e.g. elevators)

Aside:

- Basic control network (for larger objects)
- Cadastral work
- Documentation of final building



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Profile board / Alignement stage

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During construction work:

Very limited tasks for the surveying profession

Mainly:
Manual solutions

Quality and Productivity Requirements

Improving importance of QUALITY during the construction process

Phases	**Important**	**Less important**	Not important
Planning+ contracting	**Costs**	**Time**	Quality
Realisation Phase	**Time**	**Costs**	Quality
Final Control + Usage	**Quality**	**Costs**	Time

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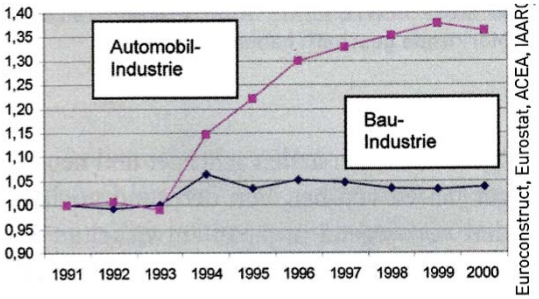
Tendencies in Construction Industry

Improve quality of buildings,
i.e. of the final construction work
(life-cycle requirements, often associated with PPP)

Improve productivity,
which is low in relation to other industries



Divergent development of productivity in different industrial branches

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Specific tasks to achieve these goals

- Development of a continuous and better quality model
- Solve the interface problem between different working groups
- Growing application of pre-fabricated elements
- More automated construction processes

Solution is only possible, if more attention is given to **geometrical aspects** and **valid reference coordinates** are introduced:

No crane, no robot and no worker can position and orient a wall, a casing or a prefabricated element, without :

=> **knowing, what the reference position is** (defined absolutely or relatively)

=> **having this theoretical information available always and everywhere**

To fulfill these requirements

- Position and orientation of each buildung segment/ element has to be predefined in a 3D-coordinate system
- The dimensions of each element have to be known, either as design quantities or as actual value
- This geometry information has to be made available everywhere and at any time on a complex construction site

=> Surveying profession is not prepared for these tasks

No other discipline either

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Geometrical Description of a Building

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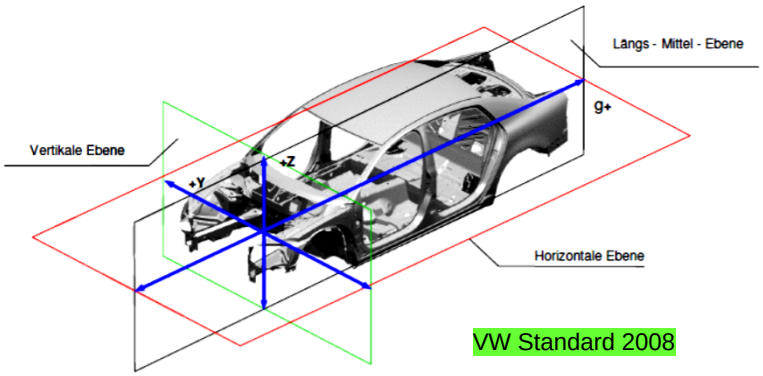
Concept of Reference Points

(Car production industry had problem to improve productivity 20 years ago)

Introduction of the **Reference-Point-System (RPS):**

Spatial description and assignment of each construction element, including the absolute size of all modules



VW Standard 2008

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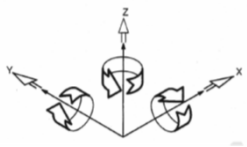
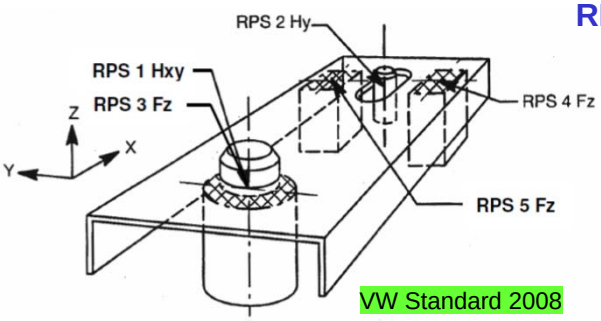
Features of Reference Point-System in car-production industry



Mathematics: 3 translations and 3 rotations are possible for each element



VW Standard 2008

RPS-Solution:

1 round hole/bole fixes position in x and y **(Hxy)**

3 pick-up points, pads or surfaces to define z-component, rotations around x and y **(FZ)**

1 long hole avoids rotation around z-axis **(Hy)**

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3D-position for each element of a car

Feld Sect.	RPS / F.-Pkt./ Funct. point	Globale Koordinaten Global coordinates x	y	z	Aufnahmeart/ Bemerkung Mounting type/ note	Bezugspunkt: Reference point x: 515 y: 275 z: 725 / Theor. Drehwinkel um Achse Theor. angle of rotat. around axis x: y: z: / Nennmasse/ Nominal sizes AE x/a	AE y/b	AE z/c	Toleranzen/ Tolerances x/a	y/b	z/c	
	1Hxy . .	515	275	725	Loch Ø 14,5+0,2	0	0	0	0	0	–	.
	2Hx . .	520	365	725	Langloch 13+0,2 x 26+0,4	5	90	0	0	±0,5	.	.
	3F . . z	515	275	725	Fläche Ø 34,5+1	.	.	.	±1	±1	0	.
	4F . . z	600	380	725	Fläche 10+1 x 20+1	85	105	0	±1	±1	0	.
	5F . . z	490	385	725	Fläche 10+1 x 20+1	25	110	0	±1	±1	0	.
	6f . . z	610	275	725	Fläche 10+1 x 20+1	95	0	0	±1	±1	±0,5	.
	a 1	595	350	725	Loch Ø 8+0,2	80	75	.	.	.	.	0,2

VW Standard 2008

Transfer of Reference Point-System to construction industry requires :

1. **Detailed geometrical description of all elements**
   Walls, pillars, ceilings, stairs, windows, etc.
2. **Determine position in 3D-coordinate-system**
   Position and orientation for all elements
   Valid for manually or pre-fabricated elements
3. **Determine dimensions of all elements**
   Theoretical values or actual ones
4. **Store this information in central data base**
5. **Make this information available at working place**
   Communication links, indoor positioning,
   additional identification of elements (RFID), ...

What does this mean for practise ?

- Contradicts dramatically to current practise (at least in Germany)
- At beginning just the architectual design exists. Then knowledge on building is growing
- Golden rule:
  „All geometrical quantities have to be taken at the working site“
  => No planning in one step
  => Deviations from theoretical geometry are tolerated

Geometry (role of surveying engineer) is more important for: Tunneling, High-Speed Traffic Lines, Machine Guidance and Large Bridges

Require position and orientation information for each building element in „global 3d-coordinate system“

Example:

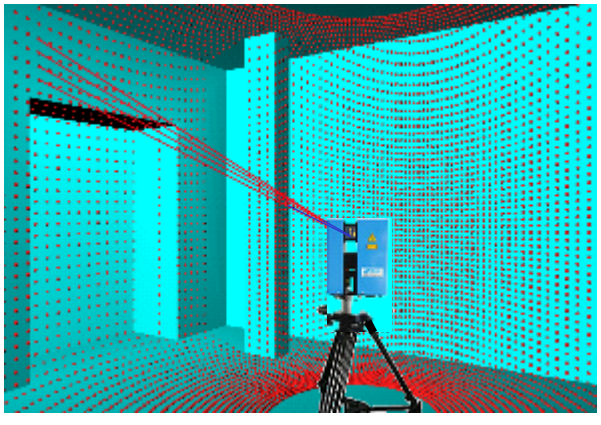
piles, walls, galeries

windows, doors

One possible step towards this objective

Simultaneous Positioning and Setting-Out

Potential of Terrestrial Laser Scanning (TLS)

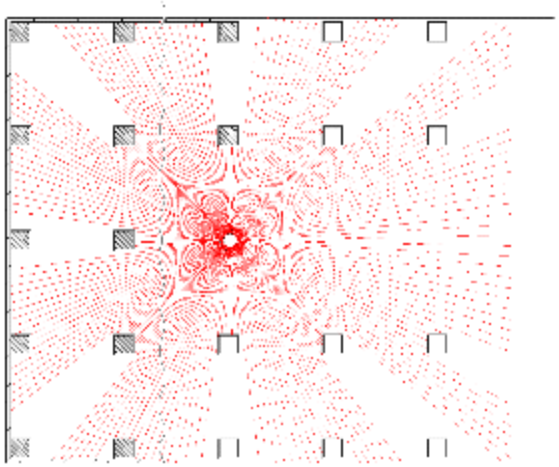


Captures geometry of arbitrary objects without any marks

Works automatically and autonomously

Allows data exchange with central computing unit

Simultaneous Positioning and Setting-Out



Existing section of construction

Elements to be constructed

Idea:

Position TLS on construction site continuously.

The position of the TLS is variable.

Simultaneous Positioning and Setting-Out

Step 1: (Backward positioning)

- Determine position and orientation (POSE) of TLS in respect to already existing building sections.
- Prerequisite is a complete and actual digital documentation of all construction progress.

=> Existing building sections contain coordinate reference

Step 2: (Forward Setting-Out)

- Pre-defined construction model with POSE for all new elements exists
- Setting-out and control of actual manual work and of assembly work for pre-fabricated elements

=> If modifications occur, they have to be documented and included in digital building model

Work flow for Simultaneous Positioning and Setting-Out

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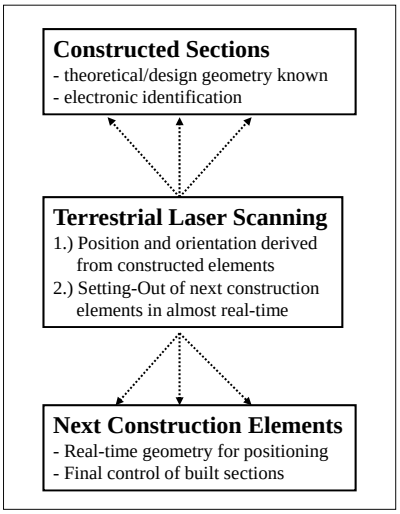

Summary

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1. Presentation focusses on geometrical aspects of construction process for standard office buildings.
2. Concept is proposed, how detailed geometry information can be made available within a growing building environment.
3. Prerequiste is detailed knowledge on all construction elements and their theoretical position.
4. This knowledge has to be stored in data base and made available at working site.
5. The new concept of „Simultaneous position and setting-out“ might be a first step to achieve this goal.

By this concept a stronger participation of surveying engineering in future, automated construction processes seems to be possible