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Connection of Floor Systems to Columns - Conventional and Advanced

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Summary

Conventional and advanced joints, the development of modelling and the component method with assembly and transformation will be described. A summary of the work done in Innsbruck in this field complemented by application aids will be given.

1. Introduction

Connections between floor systems and columns are important elements in view of design and economy of buildings.

Steel beam-to-column connections in building frames are called **conventional connections**. The floor slabs, which are or are not connected to the lower floor beams, were not integrated into the connection. They were even clearly separated from the column by a gap. This is uneconomic but there was no research available for design of the interaction between the floor slabs and the columns.

In **advanced composite connections** the floor slabs connected to the floor beams below are included in the connection to the column. In a further step the floor beams themselves are already integrated into the floor slabs (slim floors) and connected to the column. This is much more economic because the steel structure can be erected in a very simple way with steel beam-to-column connections and after concreting of the floor slabs the connections automatically get high stiffness, strength and rotation capacity.

The connection between the floor system and the column is only one part of a **joint**. The second one is the part of the column within the depth of the floor, see Fig.1,2.
The basic idea of the research was to study the non-linear member force-deformation behaviour (M-Φ) of the joint as a separate element with finite size.

2. Non-linear Behaviour of a Joint

2.1 Kinds of joints

Fig.1 shows some examples of conventional and advanced joints.

2.2 Joint Modelling

In Fig.2 the development of joint modelling is shown. Conventional global analysis assumed rigid joints of infinite small size. But as any real joint has a finite size deformations occur under relevant member forces. So in this traditional view the beam and column stubs (bj, hj acc. Fig.2,3) can be understood as a part of the deformation of the real joint.
The first step of improvement was to regard the joint as a separate element of finite size. In [1] the idea of the so-called component model was published for the first time.
The second step was to describe the force-deformation behaviour of all individual components by non-linear translational springs [1,2,3].

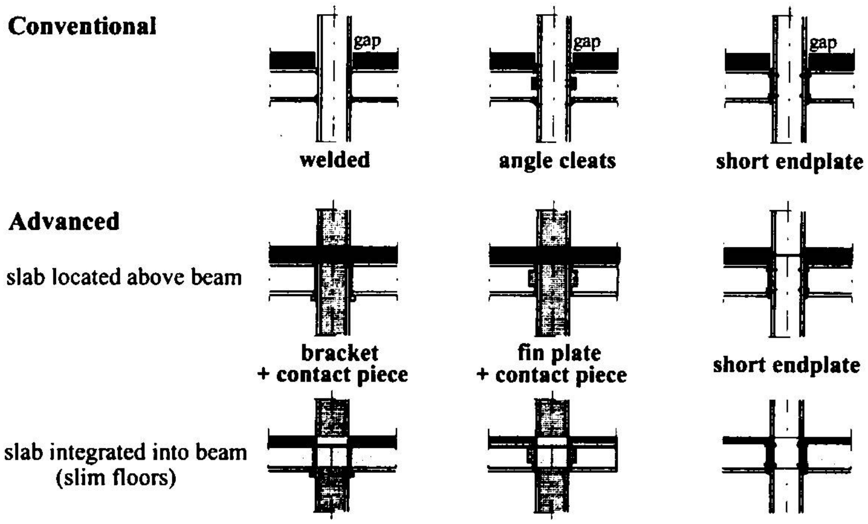


Fig. 1 Kinds of joints

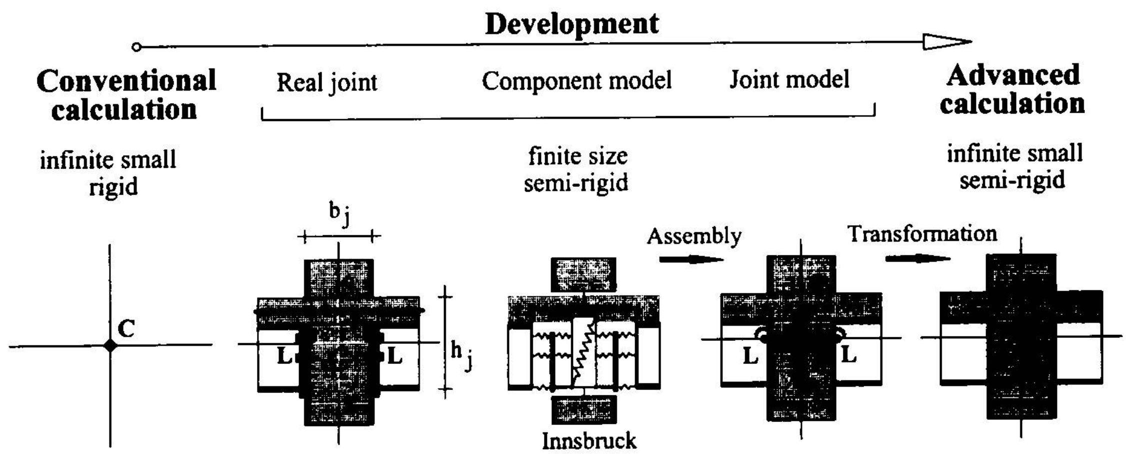
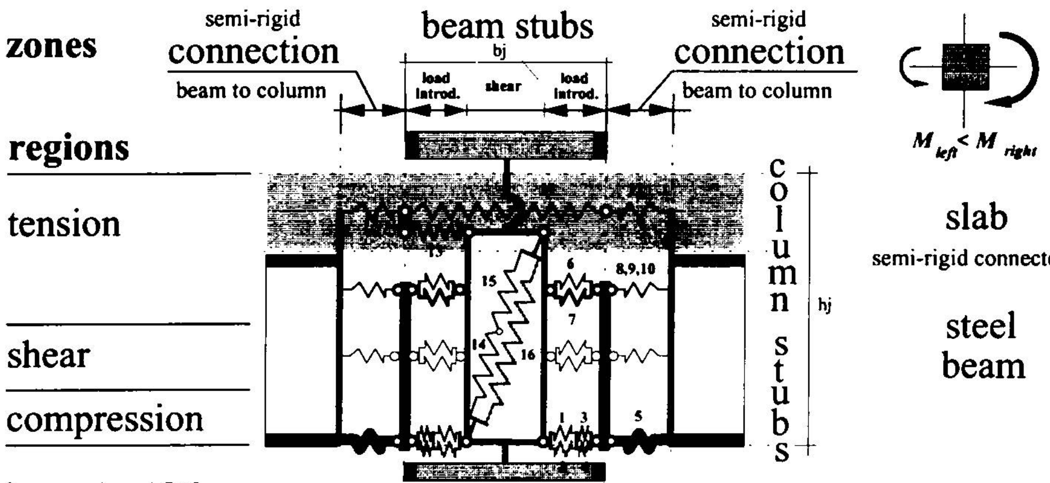


Fig. 2 Joint modelling

In the third step the translational springs are assembled to rotational springs in L and S. The rotational spring in L includes the loadintroduction into the column and the deformation of the connection. The rotational spring S represents the shear deformation of the part of the column within the depth of the floor. In the global analysis the parts of beams and columns within the region of the joint are set infinite rigid. All deformations of the joint are represented by the rotational springs in L and S forming the Innsbruck Joint Model.
For simplification in the fourth step the rotational springs in L and S are transformed back to the centre C.



for example: 1,R12
└ ref.no. within master ref.
master reference

DT ... doctoral thesis
MT ... master thesis

No.	component	zone	region	column section DT I	MT I	DT □○	MT □○
1	interior steel web panel	stubs	compression	2,R3 3,R4	3,R11 3,R12 3,R13 3,R15 3,R16	8 9	10 11 12 13 14
2	**concrete encasement**	stubs	compression	3,R4	3,R17 3,R18	8 9	10, 11, 12, 13, 14, 15
3	exterior steel web panel (column flange+local effects)	stubs	compression	3,R4	3,R13 3,R15	8 9	10, 11, 12, 13, 14
4	**effect of concrete encasement on exterior spring**	stubs	compression	3,R4		8 9	10, 11, 12, 13, 14, 15
5	beam flange (local effects), contact plate, end plate	***connection***	compression	3,R4		8 9	
6	steel web panel incl. part of flange, fillet radius	stubs	***tension***				
7	stiffener in tension	stubs	***tension***				
8	column flange in bending (stiffened)	***connection***	***tension***	2,R5			
9	end plate in bending, beam web in tension	***connection***	***tension***	2,R5			
10	bolts in tension	***connection***	***tension***	2,R5			
11	**reinforcement (within panel) in tension**	*stubs / conn.*	***tension***	3,R5		3,R5	
12	**slip of composite beam (due to incomplete interaction)**	*stubs / conn.*	***tension***	3,R6			
13	**redirection of unbalanced forces**	*stubs / conn.*	***tension***	3,R5		3,R5	
14	steel web panel in shear	stubs	*shear*	2,R4 3,R3	3,R9 3,R14	8 9	10, 11, 12, 16
15	steel web panel in bending	stubs	*shear*	3,R3	3,R9	8 9	10, 11, 12, 16
16	**concrete encasement in shear**	stubs	*shear*	3,R3	3,R9	8 9	10, 11, 12, 16

Fig. 3 Innsbruck component model

2.3 Component Model

Fig.3 shows the Innsbruck component model considering all relevant components of conventional and advanced joints. In numerous tests the non-linear force-deformation behaviour was studied in so-called component tests. Fig.3 gives an overview of all component tests and corresponding literature acquired in Innsbruck. It has been proved on tests on full-scale joints that the component model is adequate [3,R3,4,5]. The test results were brought into the international databank SERICON [4,5] and were used for standardisation in [6,7].

2.4 Assembly

In Fig.4 the assembly procedure is shown. Out of the tests models for each individual component were developed as translational springs, describing the stiffness, strength and ductility analytically. The individual springs then are joined together in series or parallel forming spring groups. These spring groups are finally assembled to rotational springs in L (loadintroduction and connection) and S (shear).

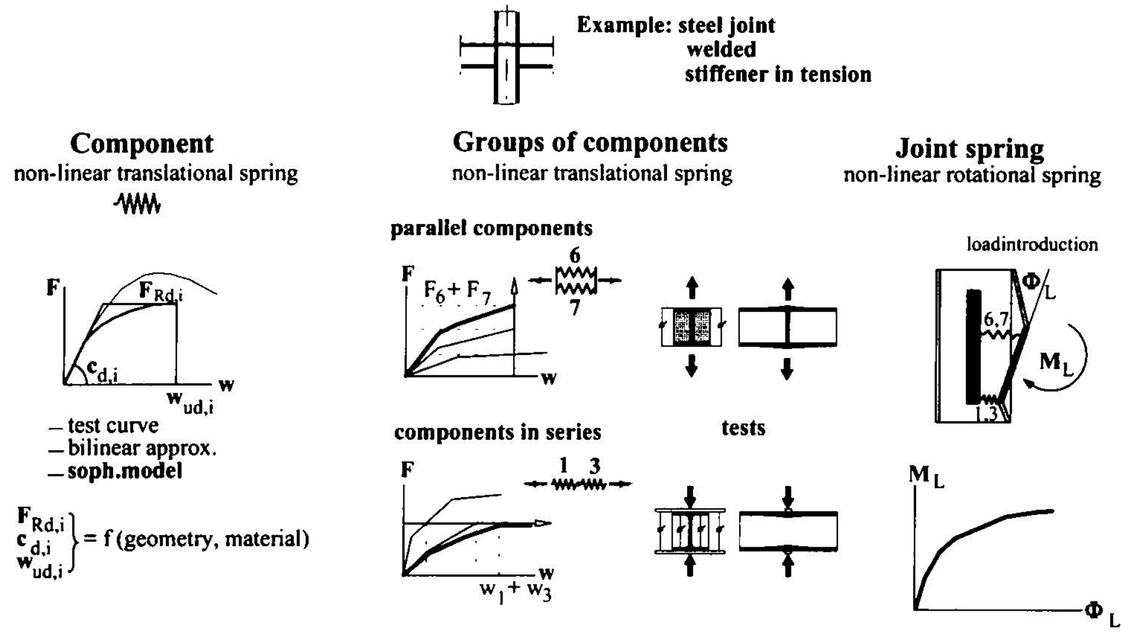


Fig. 4 Assembly

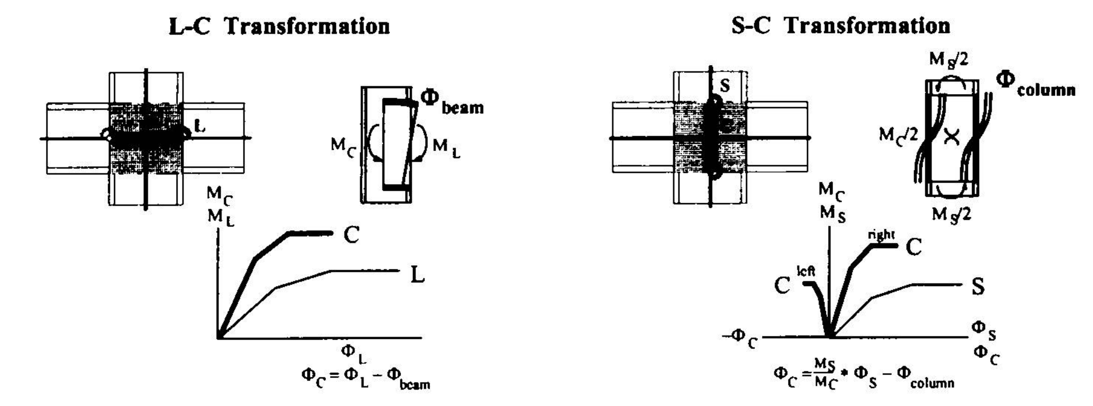


Fig. 5 Transformation

2.5 Transformation

Transforming the rotational springs in L and S to C it must be considered, that the beam and column stubs in the region of the joint get deformations from the global analysis, Fig.5. So these deformations, which mainly depend on the joint itself, have to be subtracted from the deformations of the joint not to have this influence twice in the global analysis. It should also be noted especially for big joints in relation to the structure that the moment increases from S and L to C depending on the global analysis.

3. Application aids

The author realises that until now the practical application for all this new knowledge is rare. In Austria only one building was designed making use of all composite elements as slabs, beams, columns and joints [17]. The reason is, that practical engineers are not trained to use non-linear calculations and support like adequate tables, handbooks and software is missing.
A general problem today is the technology transfer because of missing money. The money available is just enough for the basic research but twice as much money would be necessary for the work-out of practical application rules and tables together with partners from the industry.
In Innsbruck success has already been achieved with the following efforts:

3.1 Tables for joint calculation

In two master thesis tables for short endplate steel joints and corresponding tables for composite joints were developed. The tables dealing with steel joints are useful for the calculation of erection, whereas those for the composite joints help for the calculation of the final composite structure [18,19].

3.2 Software for joint calculation

On the basis of the Innsbruck model the Module Bank System [20] determines the M-Φ-curves of steel and composite joints. As it is an open system it can continuously be adopted to the latest knowledge, especially considering the assembly and transformation as well as new components like loadintroduction and shear in hollow steel and composite column sections.

3.3 Software for frame calculation

With the software [21,22] sway frames including the non-linear behaviour of the joints can be analysed.
An instrument for the calculation of continuous beams considering the material non-linearities, the tension stiffening effect, the non-linear interaction between the beam and the slab and the non-linear behaviour of the joints will be provided in [23].

4. Conclusion and Acknowledgement

Advanced composite joints have the advantage that the slab of the floor is integrated into the joint. This is especially important for the execution of the building in view of costs. Out of the component method a lot of new joint configurations with simple erection methods can be derived in the future. The theoretical basis is well advanced, so the practical application should be forced.

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