AN ARCHITECTONIC APPROACH OF CHOOSING A SPACE FRAME SYSTEM

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Abstract

Nowadays there are a tremendously number of trade mark space frame systems. When a designer or an architect choices a for him well known system, often he will be very limited in his aesthetic design and/or faced with high costs. Making the best choice for his design two tools are given in this paper. The first one is a classification of connections for these kinds of systems. While the second reveals itself the practical relation between a space frame system type and its application field.

1. Introduction

The components of a space frame system are to define as a construction kit with a limited number of parts. The number of components is dependent on the construction principle of the system (cross sections and especially the art of the joint). The dimensions of the components are determined by the size of the acting forces. There are tremendously number of different systems; mostly of them are trade-mark.

In general the one who decides to use a spatial frame construction is an architect or designer. From his viewpoint attention focuses on the practical problems of integrating the structure in the building envelope with an acceptable aesthetic and at a reasonable cost. One of the most important items is the image of the system type in relation to the image of the designed building or structure. Some system types have the image of a high sophisticated system; for instant some types with spherical node. Others have more an utilised image like the punching or welding plate types.

Making his decision he looks also to other important items like:
– the economic measures of grid or module size;
– the possible grid or module form;
– the seized point of external forces;
– the need of purlin stools;
– the possible structure shape;
– the number of possible layers for a frame;
– the maximum number of members to one joint.

Thus choosing the right system type for a particular design is not so easy and this changes from one design to an other. Mostly an architect carries through one for him well known system type. And of course this is no the good base for the most economic choice and for the system image in relation to the building image.

2. Classification

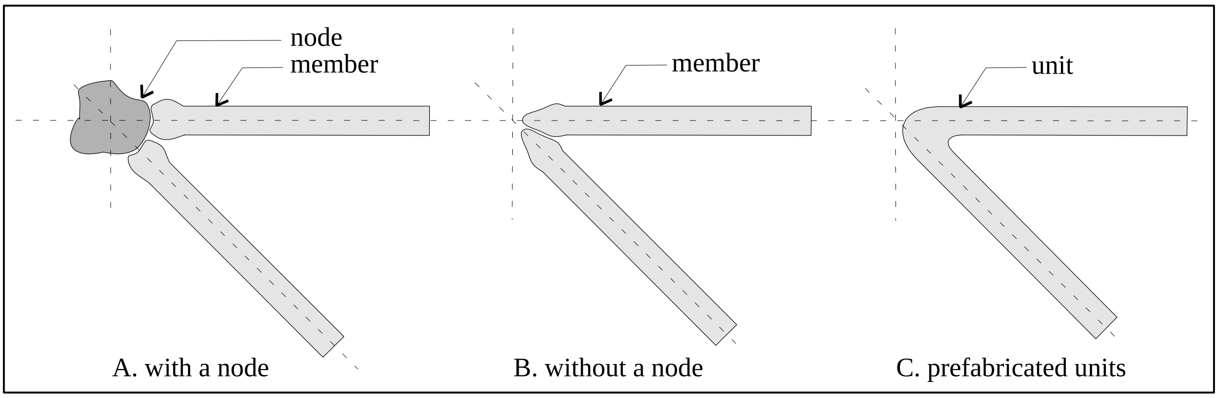
Getting a idea of the image of (trade-mark) space frame systems a classification of the structural components can be made, which depends on the particular point of view:

- construction: with or without a node; bolting, welding, flattening or bending of members; number of members on a joint.
- shaping: member cross section, member connectors, joint.

The author would suggested an extension of a mixture, because the shape is derived from the connection technique. On the other hand one can create a particular joint construction for a new system, resulting in a shape. All the connection techniques can be divided into three main groups:

A. with a node; B. without a node; C. prefabricated units.

Mostly the application of a space frame is based on architectonic terms, sometimes on constructural terms. So a complete other classification system can be made based on fact is a system representative of a certain image.



Some times an architect or designer can not find to required image of a space frame system for his design and resolves to design a new space frame system. But every year decades of new space frame systems were and are invented. The starting point for the development of a new space frame system is frequently with a particular aim like enlarging their firm work field, a easy assemblage, a cheap joint system, a very aesthetic joint system, for max. applications or for one specific situation. By virtue of different starting points a system may be used in several occasions; conform its specific qualities.

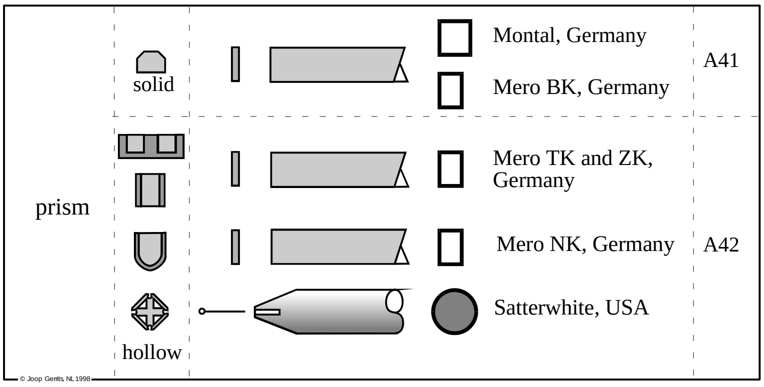
Unfortunately real new systems are and will be not invented, because everything is already been make in the past. Thus many firms and designers are copied successful systems in a way avoided copyright of the trade-mark systems.

Sometimes they think to invent a real new system but regrettably it already exists. For instance Mero KK ↔ Pantadome systems, Boyd Auger ↔ Octatube systems, Steve Baer ↔ Van Thiel systems, Spherobat ↔ NS Space systems and Orbik ↔ GS ↔ Tuball systems. Or one copies parts of several excising systems, resulting a ‘new’ system; such as the Dutch Piramodul Large Span system, being composed of the Nodus (bracing member connection) and Octatube (node) system elements.

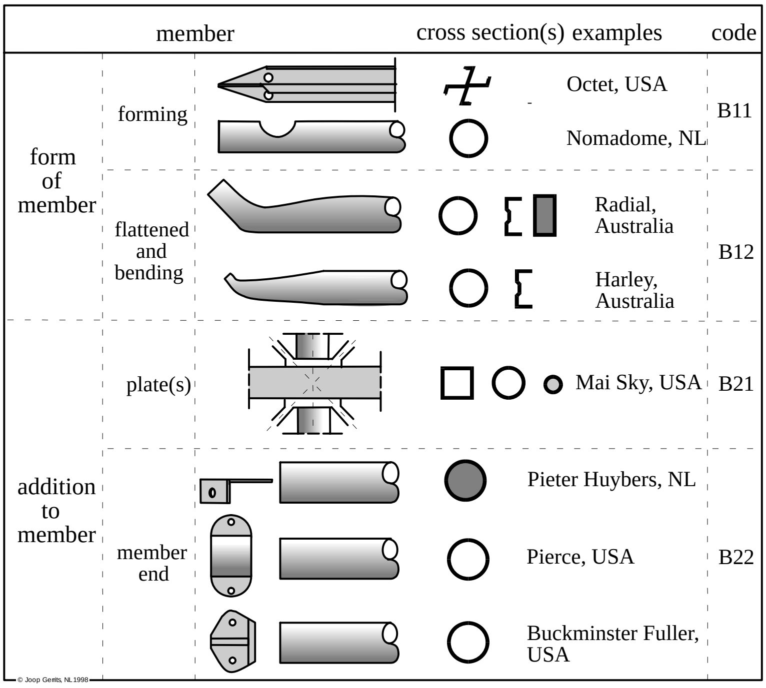
The starting point for the system classification is the standard (trade-mark) systems. Obviously every system type may be modified for a specified situation. The aim of the author was not created a complete classification system, but showing the principles of the common space frame systems.

node		connector	member	cross section	examples	code
sphere	solid				Mero KK, Germany Montal, Germany Uzay, Italy	A11
					Steve Baer, USA Van Tiel, NL KT space truss, Japan	
					Mero MT, Germany	
	hollow				Spherobat, France	A12
					NS space truss, Japan Tuball, NL Orbik, UK	
					Tuball plus, NL Orbik plus, UK	
	hollow				SDC, France	A13
	hollow				Oktaplatte, Germany	A14
					WHSJ, China	
	hollow				Vestrut, Italy	A15
cylinder	solid				Triodetic, Canada nameless, East Germany	A21
	hollow				Octatube Plus, NL nameless, Singapore	A22
					Pieter Huybers, NL	
					nameless system, UK	
disc	flat				Palc, Spain Power strut, USA	A31
					Pieter Huybers, NL	
					Tridimatec, France	A32
					Space-frame system VI, USA (former called Unistrut or Moduspan)	A33
	welded				Boyd Auger, USA Octatube, NL	A34
					Piramodul large span, NL	
					Nodus, UK	A35

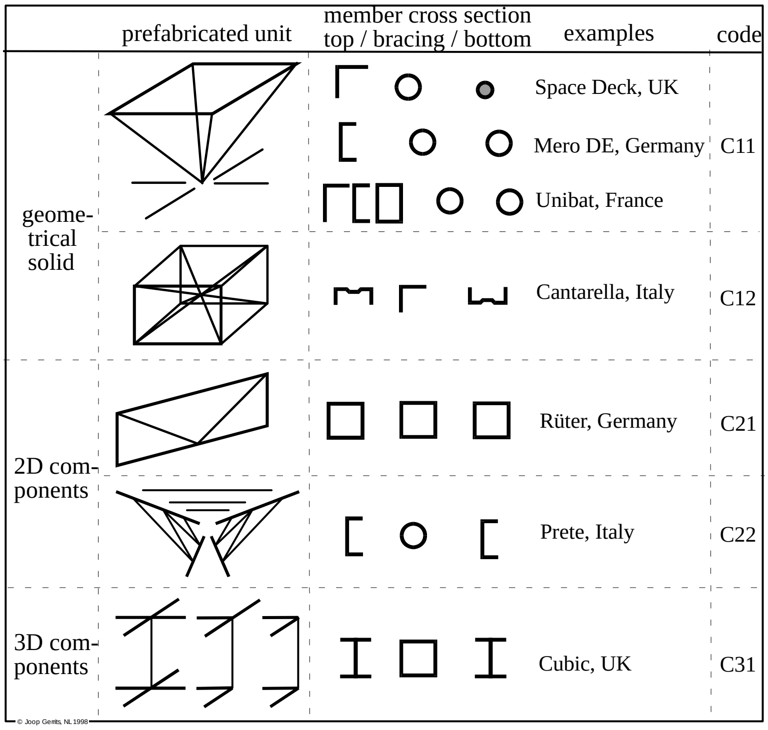
Connection types with a node, part 1.



Connection types with a node, part 2.



Connection types without a node



Connection types with prefabricated units.

3. Application field

There is of course a practical relation between a system type and its application field. With spherical node types one can easy make free shapes and not with unit types. Thus choosing a system type dependent on which technical parameter is the most important. The parameters are the grid or module form, external forces, the need of special supports and purlin stools, the space frame shape, the number of possible layers and the max. number of members.

Getting an idea of the possibilities for all researched system types some notes and reviews are given. The starting point for these is the standard (trade-mark) systems. Obviously every system type may be modified for a specified situation.

Some characteristic parameters are:

Structure shape.

Most system types can be applied as flat structures, mostly with a square grid form and with double layers. Other grid forms are also possible, but no economic as flat structures. System types for making the remainder structure shapes exist mostly out of spherical, cylindrical or prism nodes which can be applied as single or more layers (single or double curved).

Layers

Maximum number of possible layers for a structure is entirely dependent on the way of making the member link (joint). All the system types can have two layers, some can also apply as single layer (curved structures) or triple and more layers.

Grid or module form.

Of great influence on the form is the art of the node and/or the member links, the measure of member cross sections, the numbers of member connections and the required space for assembling. Nearly all the systems can be applied with square or rectangular grids. With the spherical and cylindrical nodes all forms are possible.

Grid or module size.

Speaking in general terms grid or module sizes are based on economical ground, often on the clear span of the cladding. For a prefabricated unit type the common size is about 1.5 - 2 m, excepted the Cubic system with approx. 2 to 3.5 m. For the remainder types it is approx. 3 - 3.6 m, excepted Piramodul Large Span with 5.3 m.

External forces.

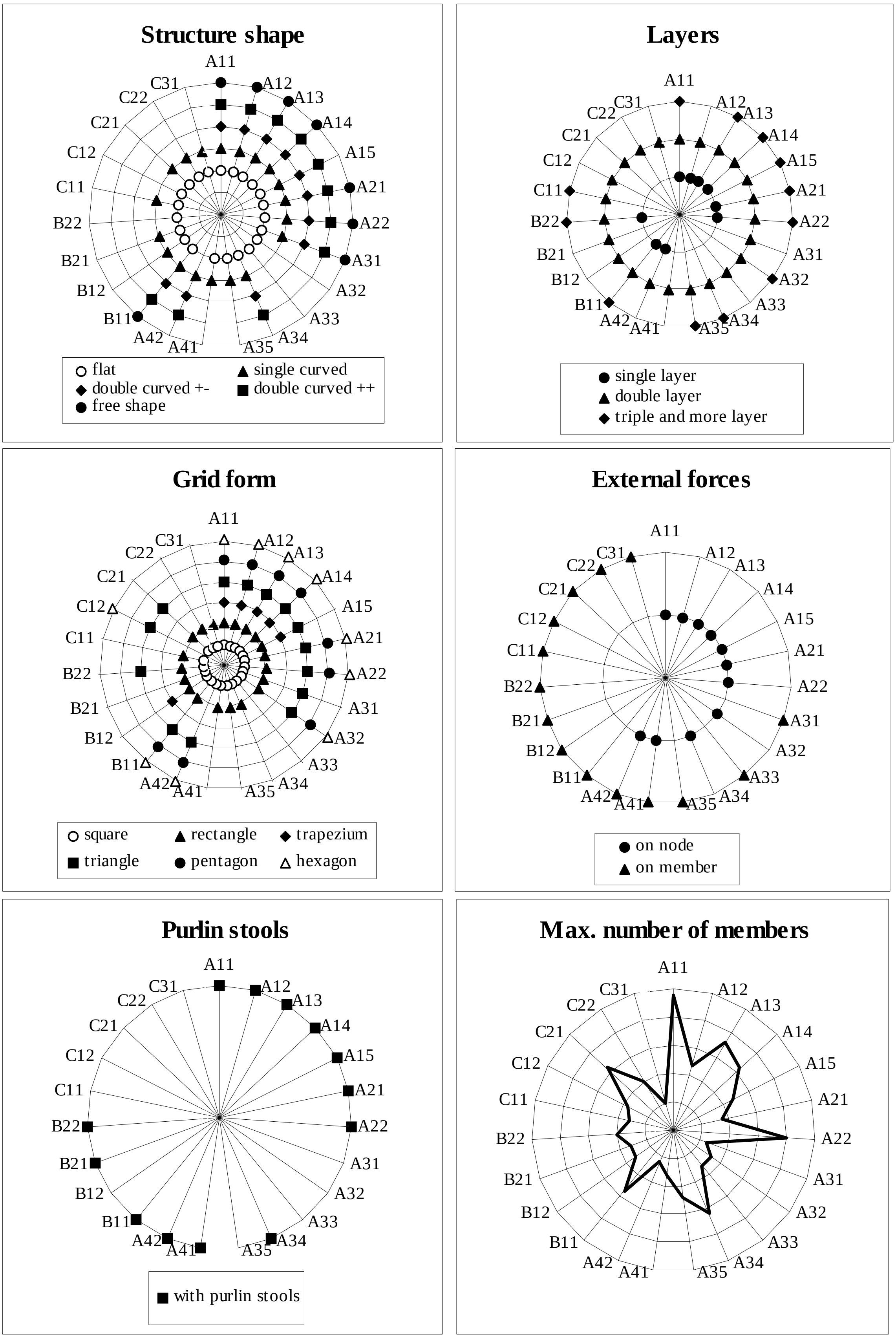
In many systems external forces may only seized on a node. In these members there are acting axial forces. By deformations in this kind of systems some secondary bending moments appear in the node-member link in every hinge connection. To limit these moments external forces may only seized on a node. Other systems can be load on the member. So they remove axial forces and bending moments.

Purlin stools.

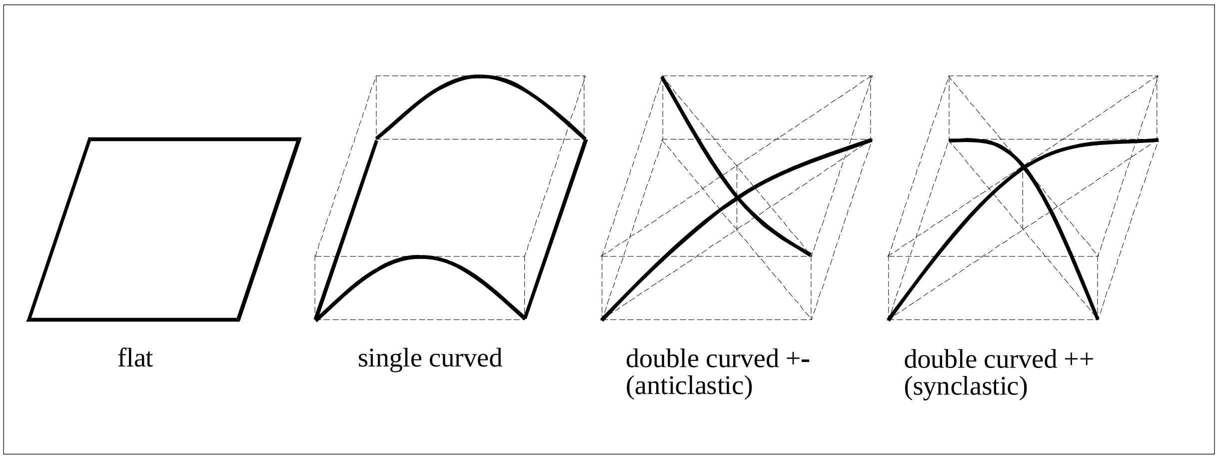
In three cases purlin stools are necessary:

- the size of the node is larger then the one of the member,
- the size of the node is smaller then the one of the member
- the external forces seize only on the nodes.

When a structure with purlin stools is covered by cladding, members and purlins run parallel on a short distance. If stools are not required then the cladding can fixed directly on the members; this is very economic. The difference of visual effect is that the cladding is floated over the space frame (with stools) or the cladding is part of the frame.



Reviews of some characteristic parameters



Structural shapes

		structure shape					number of layers			grid form						ext. forces				
code	**system type**	flat	single curved	double curved +-	double curved ++	free shape	single layer	double layer	triple and more layer	square	rectangle	trapezium	triangul	5-angle	6-angle	on node	on member	purlin stools	max. number of member	**Example**
A11	solid	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	24	Mero KK
A12	hollow (with cap)	o	o	o	o	o	o	o		o	o	o	o	o	o	o		o	12	Spherobat
A13	2 semi-sphere*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	18	WSHJ
A14	2 semi-sphere with thin plate*	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o		o	16	SDC
A15	2 semi-sphere with thick plate	o	o	o	o			o	o	o	o	o	o			o		o	12	Vestrut
A21	solid	o	o	o	o	o	o	o	o	o	o		o	o	o	o		o	9	Triodetic
A22	hollow	o	o	o	o	o	o	o	o	o	o		o	o	o	o		o	20	Octatube-dome
A31	flat (single plate)	o	o	o	o	o		o		o	o		o				o		6	Power Strut
A32	flat (double plates)	o						o	o	o	o		o	o	o	o			8	Tridimatec
A33	punching plate	o						o		o							o		8	Unistrut
A34	welded plates	o	o	o	o			o	o	o	o					o		o	16	Boyd Auger
A35	castings	o	o					o	o	o	o						o		12	Nodus
A41	solid	o	o					o		o	o					o	o	o	8	Montal prism
A42	hollow		o	o	o		o	o		o			o	o	o	o	o	o	6	Satterwhite
B11	forming the member	o	o	o	o	o	o	o	o	o	o		o	o	o		o	o	14	Octet
B12	flattened and/or bending	o	o					o		o	o	o					o		8	Radial
B21	plate(s)	o	o					o		o	o						o	o	8	Mai Sky
B22	member ends	o					o	o	o	o	o		o				o	o	10	Multi-hange
C11	pyramids (half octahedrons)	o	o					o	o	o	o						o		8	Space Deck
C12	cubics	o						o					o		o		o		9	Cantarella
C21	short trusses	o	o					o		o	o		o				o		16	Rüter
C22	large trusses (Warren)	o	o					o		o	o						o		10	Prete
C31	ridig frames	o	o					o		o	o						o		5	Cubic

* *welding assembling*

Relation between space frame system type and application field.

Supports for a structure.

A few system types need a special stanchion support for fixing on columns or other supported elements; this as result of the node shape. But the most system types use the common steel connections for building structures.

Members

Maximum number of members to one joint is especially important for free structure shape and is dependent on the grid form (see *Grid or module form*).

The quantity and the total length of the applied members is dependent on the member configuration.

The most applied space frame structure is the one with the flat shape, a square grid form and double layer. In this case the grid size is about 1/12 of the space frame clear span; the distance between the two layers (structural depth) is approx. 1/17 of the space frame clear span. The clear span area is between 30 and 80 m. Above the 80 m triple layers are necessary.

4. Conclusion

Selecting the 'best' space frame system for a specific situation is very complicated due to the many design parameters and especially to the image of a system. The image is complete dependent on the individual view of the designer. Therefore a general rule can not be given. In the future there will be developed a computer decision tool for choosing one or more trade-mark space frame systems based on the required architectural qualifications of a designer.

Characteristic for all systems is that the member ends are worked: welded, flattened and/or bent. Also all systems are bolted together on the building site, except for the two system types namely A13 and A14.

Generally speaking systems with spherical and cylindrical nodes are applied for all structural shapes with the necessity of using purlin stools for cladding or glazing. Systems with disc nodes, without nodes and with prefabricated units are mostly applied as flat structures without purlin stools. The prismatic nodes are developed generally for single or double curved structure shapes with glazing directly fixed on the members. All system using circular cross section members need always purling stools.

The most important issues are the acceptable aesthetic and reasonable costs. It is only possible making general conclusions about the relation between the aesthetics and the system types. This in terms of a high sophisticated or utilised system types. Also attention have to make about the costs because after the complete construction of the building envelope a cheap produced and well looking system may be expensive compared to other systems.

Reference

Gerrits, J.M..; Morphology of space frame connections. In: G.C. Giuliani (ed); Spatial Structures: Heritage, Present and Future (Proceedings of the IASS International Symposium 5-9 June 1995), SG Editoriali, Padova, 1995, p. 171-178.