SPECIAL PROJECT

JOINTS IN MODULAR SYSTEMS

by
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Guide
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APPROVAL SHEET

The special project titled "*Joints in modular systems*" submitted by **Lalitesh Mandrekar** has been approved in partial fulfillment of the Masters degree in Industrial Design.

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I take this opportunity to express my thanks to Prof. A.G. Rao for his invaluable guidance in understanding the subject.

Lalitesh Mandrekar

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Introduction

Broadly defining a joint is a structural relation between two individual bodies so that mechanical forces are transmitted from one body to the other. But many other aspects such as aesthetics and compatibility with the system or product functions also contribute to design a joint. This project is a study of various joints in modular systems and focusing on problems related with panel joinery system. Various principles in joinery are analyzed and some different ideas are suggested for joining of FRP panels.

About modular joints:

- Joints in modular systems are designed for a particular set of modules considering their sizes, shapes, materials and varia tions.
- Modules and joints are developed together and joints add to the character of a modular system.
- Joints determine configuration of modules.
- They allow fast assembly and knock-down of the prefabricated modules.
- Modules and joint elements are reusable after knock-down with out any working on the material.

Factors involved in modular joint design

While designing joints in a system certain factors are considered and these factors influence the design in varying strengths depending on the requirements of the system and other circumstances. These factors are discussed here.

Forces

A joint develops a physical bond between two parts or elements and hence it transfers forces from one element to the other. Hence transfer of forces is a major criteria while designing any joint.

Forces to hold the elements together

Two bodies with respect to each other have six degrees of freedom i.e transitional and rotational motions about x,y and z axes. According to the requirement of module configuration and its function certain motions are to be restricted. This is done by the joint and various forces are used to do this function. These forces could be mechanical, gravity, friction, magnetic etc.

Stresses induced in part material

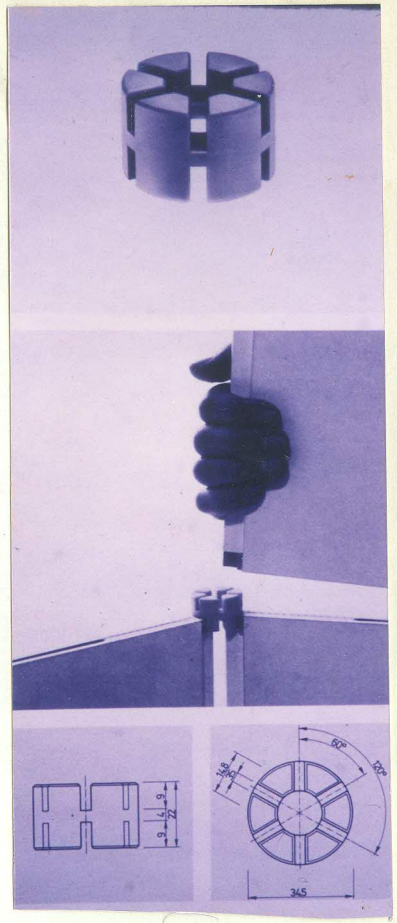
Because of joint mechanism stresses are developed in the module or part material, and if the material fails to withstand them it will break hence while designing the joint, it is very important to carefully utilize the strengths of the material. For instance if the material has less skin strength, the area of contact with the holding element and part surface should be more so as to avoid localized stress. Hence the design should avoid the stresses which may fail the material.

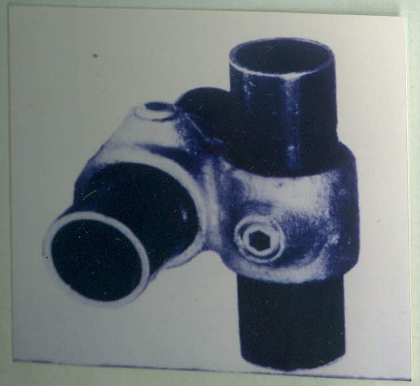
Time

Modular systems have an advantage over custom made systems that they are prefabricated in parts and the modules are assembled on the site to build the whole system within less time. Hence the joiner should be designed so as to reduce the time required for assembly of modules as well as their knock -down.

Many factors are involved in actual assembly time reduction, some of which are listed below. These factors are related only to the joinery and not module and system design.

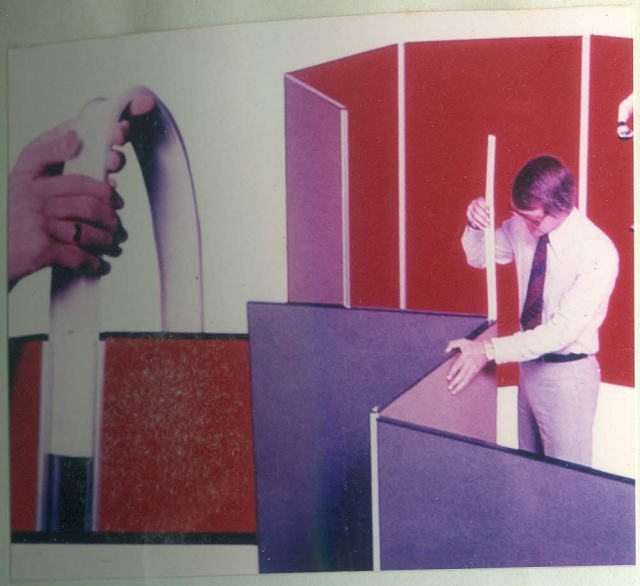
↑ GRAVITY →



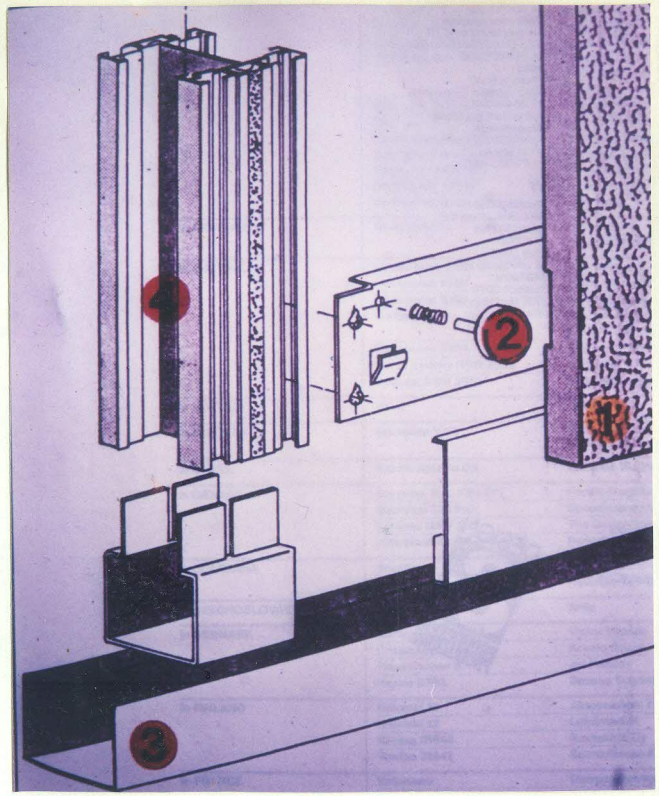


← FRICTION

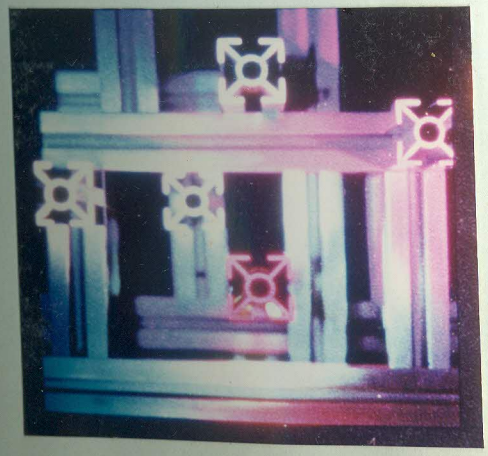
JOINING FORCES



↑ RUBBER EXTRUSION



MAGNET ↑



←MECHANICAL

JOINING FORCES

Standardized joinery: Using similar joints wherever possible brings uniformity in the assembly procedure and hence resolves complexity of using different components, tools etc. which in turn reduces the assembly time.

Reduction in no. of joints: This can be explained by an example of fixing a square panel on a frame which can be done by using say 12 screws which take time in lightning but if the same panel is fixed by four bolts with breading running over the edges, then time will be saved.

The knock down time can be still further reduced than assembly time since while knock-down matching of tolerances etc. is not required hence by use of quiet release mechanisms, it can be made to dismantle the structure faster. Also breaking off the joints can be done.

Access

In an ideal case the changeable modules should be removed without disturbing other modules. But practically it is very difficult because some way or the other., the modules are related to each other structurally or formally. Hence module shape and joint location are very important to give maximum access to the joint for operating.

Hence while designing the joint back and forth thinking is necessary regarding

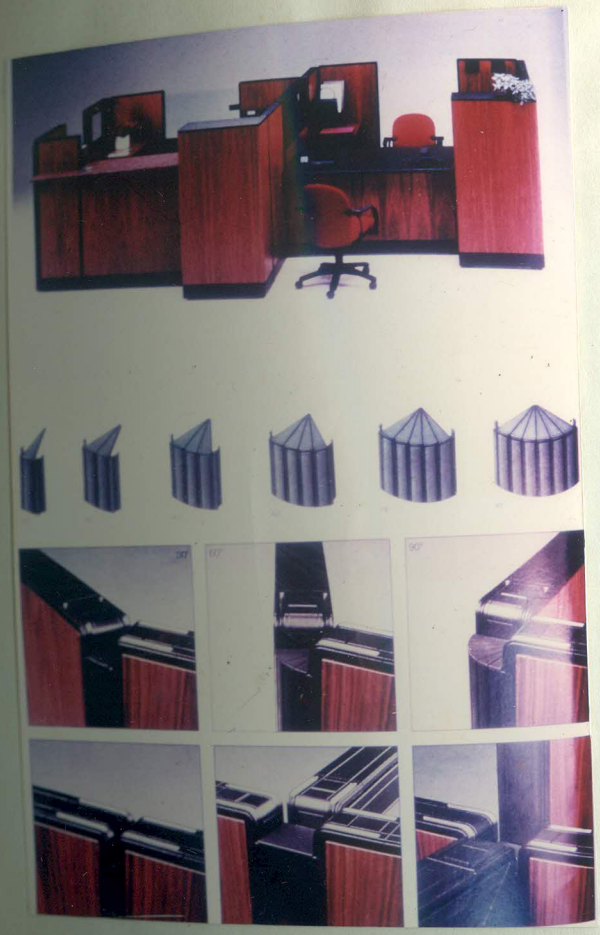
- hiding of joint
- tool size and shape
- action for operating the joint.
-

Tool

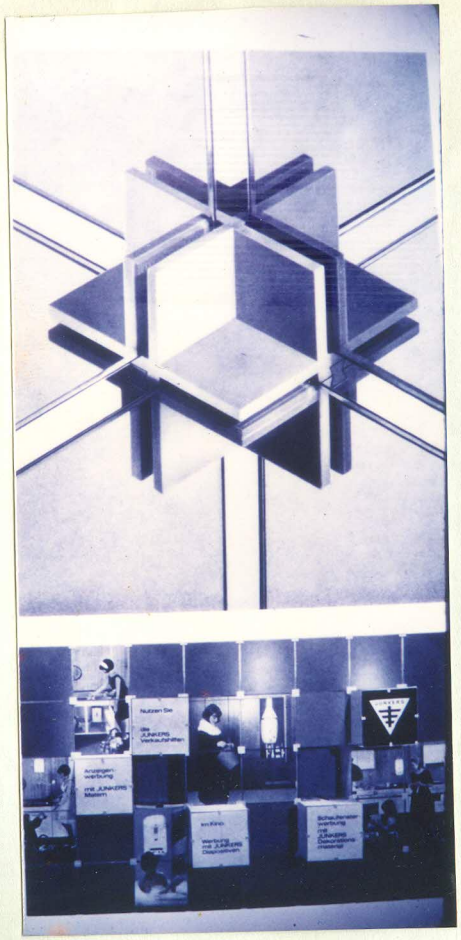
The kind of tool used for operating a joint is a very important factor. Again ideally a joint should not require any tool for assembly and knock-down but again the force requirements, access the joint require some tool many a times. The tool required for operating the joint decides many other features in the system like access and direction of fitting the module etc.

Following factors are considered while deciding on tool.

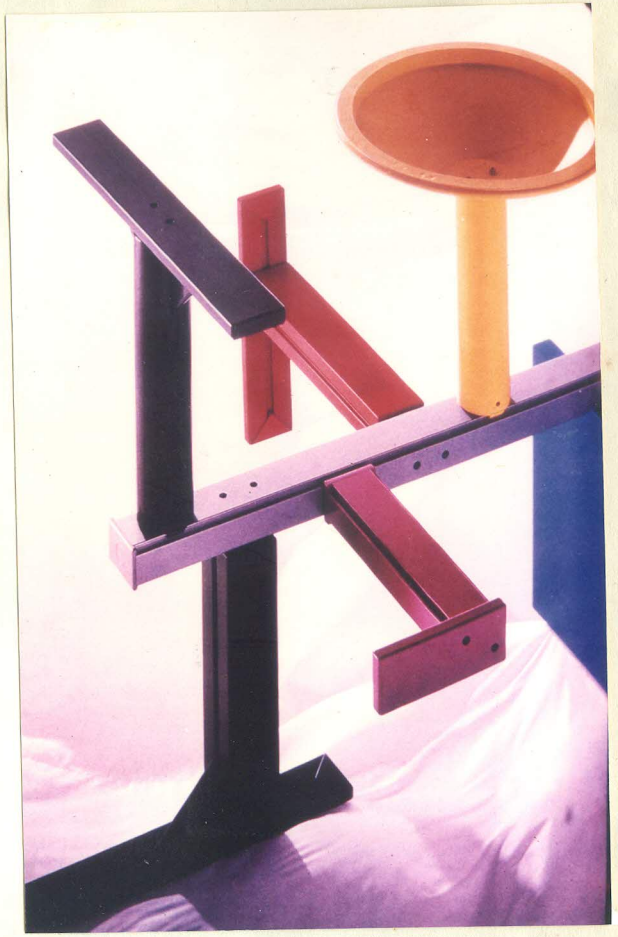
Availability: The tool should be available easily. Special tool requirements make it difficult to interchange the modules particular for the user (ie non skilled personnel) Hence many joints are designed which require



ADDITIONAL ELEMENTS ↑



JOINT STRUCTURE ↑



MODULE STRUCTURE ↑

PROPAGATION OF MODULES IN SPACE

no tool or even coin operated, especially those which require frequent doing and undoing like service duct openings etc.

Tool size: Tool size should be as small as possible for it needs less access space. But this is governed mainly by the operating force/torque required to tighten the joint.

Powered or manual: Manual tools are handy and easily available but powered tools are preferred for speed and higher force applications.

Size

Size of the joint affects the visual elements as well as the bulk in the system hence preferably the size is made as less as possible. The factors affecting the size are

Force resistance: The geometry and forces on the joint require enough size so as to give resisting force or torque.

Material properties: Skin strength and stress concentration in the module material sometimes require more surface area or bulk to be utilized by a joint.

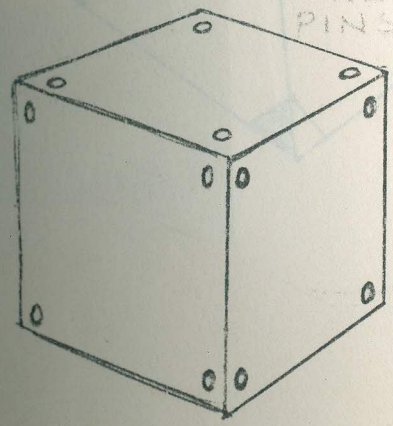
Mechanisms and principle of operation: The basic principle of operation for the joint requires definite no. of parts which in turn affect the size.

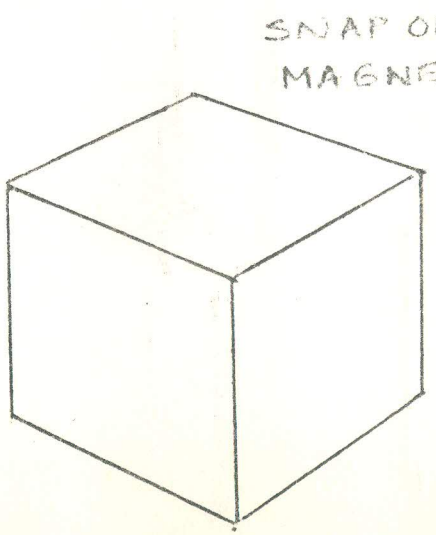
Visual element:

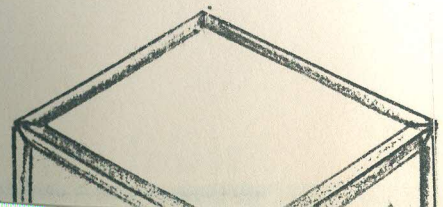
While designing a modular system, joinery affects the aesthetics strongly since the no. of joints is high Unlike other fabrication methods, in modular systems, there is no post joint finishing which will hide or finish the joint Hence all the joint elements are prefinished and care has to be taken that after assembly, the joint form and finish does not affect the affect the system aesthetics adversely.

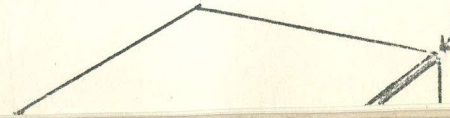
All the constraints of access, force requirement material limitations, operation for fixing etc. affect the size and shape of joint elements which in turn characterise the system aesthetics. Hence it is a tough task for the designer to keep balance between the engineering and visual aspects of the system.

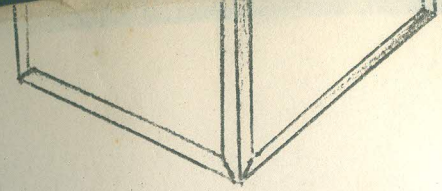
JOINARY & VISUAL CHARACTER

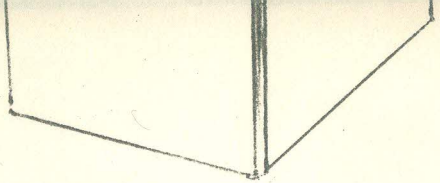


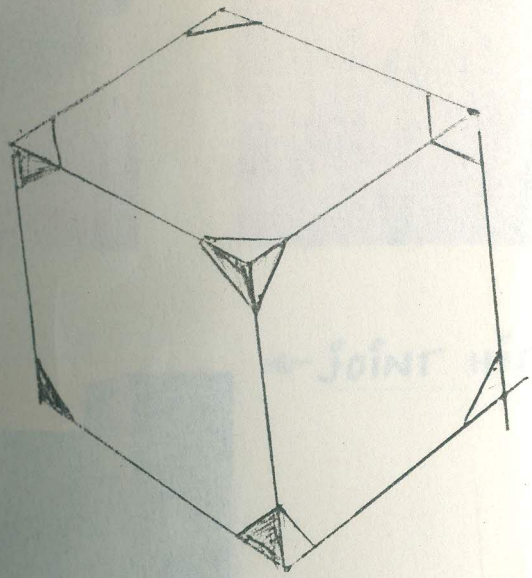


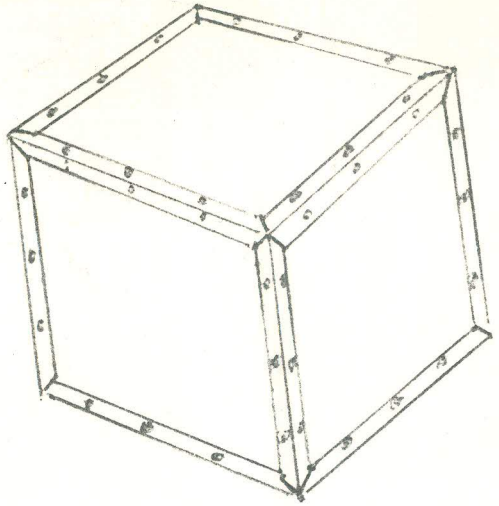


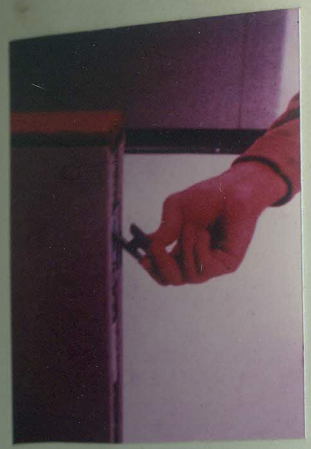


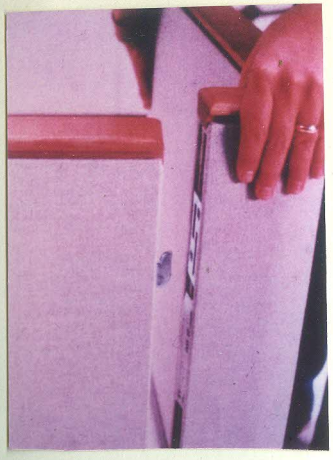




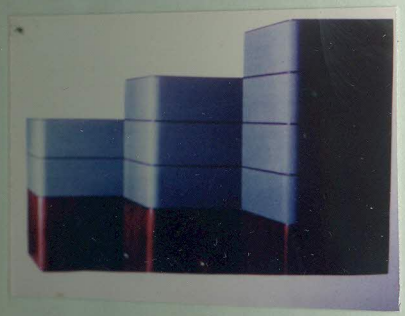




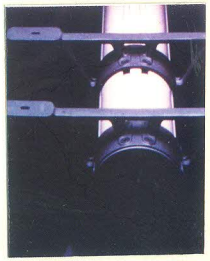




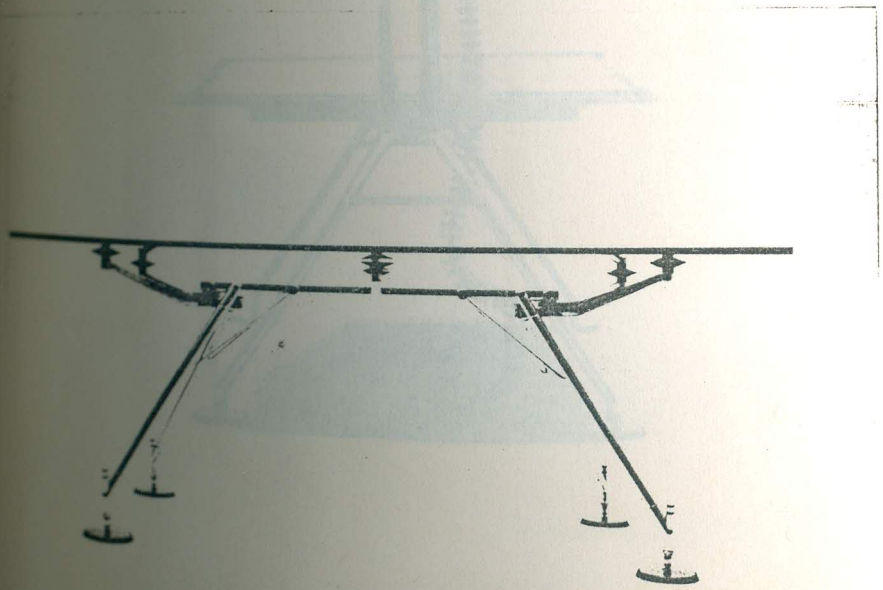
← JOINT HIDDEN



JOINT TREATED AS VISUAL ELEMENT →



VISIBILITY OF JOINT



Joinery in a modular system gives a character to the system. This can be seen through the adjustment sketches. The sketches show a cube made out of flat panels which remain constant in all cases. Only the joinery is changed. The example shows that even with basic differences in joining methods the same cube looks very different. the effect is further enhanced when some specially designed joint elements are used. The joints in modular system are visually treated in two ways.

The joint elements are hidden by the module material so that at joining surface only the parting line between two modules is seen and the joint does not break the visual continuity between two modules

The other way is that the joint elements are treated as visual elements and enhanced by difference in finish, colour, form etc.

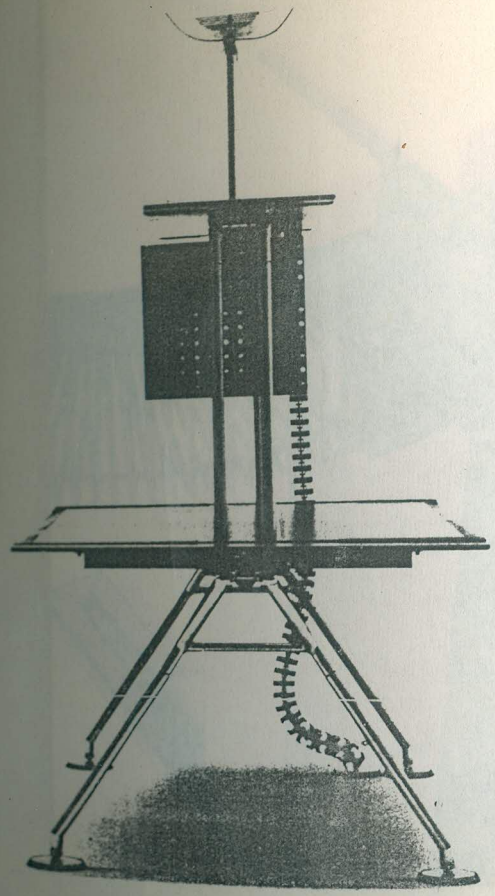
Case study : Sistema <Nomos>

A very prominent example of joinery playing an important role in function and visual character of the system is the table and office system designed by Norman Foster called Nomos. The system has a basic element of the system which is a table that characterises the whole range. The table consists of a tube which acts as the backbone and supports the legs, work surface superstructure etc. The variations in the range is caused by many alternate designs of the elements of legs, feet, superstructure extensions which are fitted to the basic backbone and the division of modules is in such a way that it provides options at every joint. A major visual treatment of the joinery makes an impact. The whole system looks quite machine like because of exposed joints and skeletal structure using hard, sleek chrome plated tubular modules.

Joinery in this case is the major issue in the development phase and even new machines and forming processes are developed to achieve the required results.

Tolerances and adjustability

In modular system when modules are assembled together the errors in the dimensions go on adding and at a point it becomes noticeable and it may even make it difficult to fit the next module. To avoid this high accuracy in module dimensions is required and higher accuracy calls for complex and costly methods of manufacture to be employed. This can be avoided



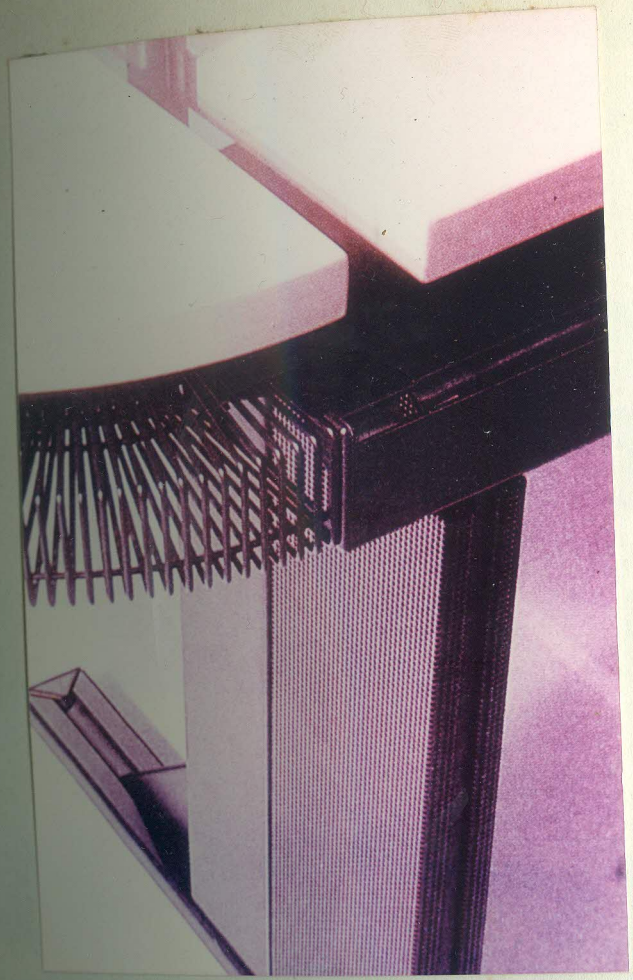
by giving more tolerances in joint and providing adjustability taking care of degrees of freedom to be restricted Adjustability in joint not only provides error correction but can also take care of thermal stresses in the modules in outdoor systems

Manufacture/Cost

For tackling the different aspects discussed before, it is sometimes needed to use special parts which require costly production methods and in turn tend to increase the cost of the system. reducing no. of different parts required by standardizing the joints can reduce the cost. An overall value of a special joint has to be determined ie its contribution to resolve assembly procedure, reduction in time, visual upgradation etc. actually determine whether t use a specially designed non standard element.

Areas of application and their requirements

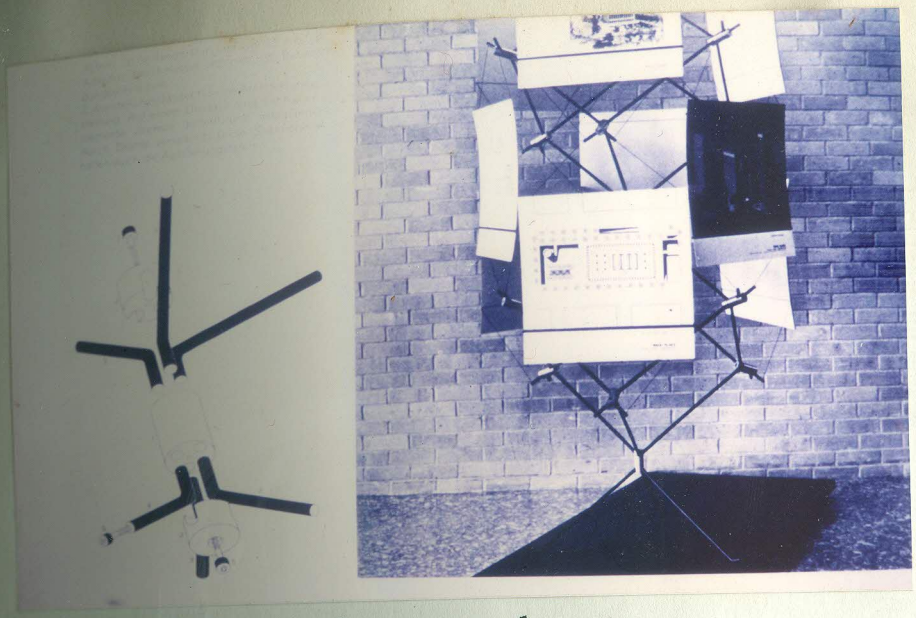
Modular systems are used in many areas like furniture, lighting, street furniture, exhibitions, and even architecture and each area of application needs certain features from a joint e.g. A panel fixed on to the structure of partitioning should be removable from front but a panel fixed on structure of a booth in public place should not be opened from outside and i t should be water tight as well.Or a pipe joint in fencing system need not be carrying electrical cable as a pipe joint in lighting system



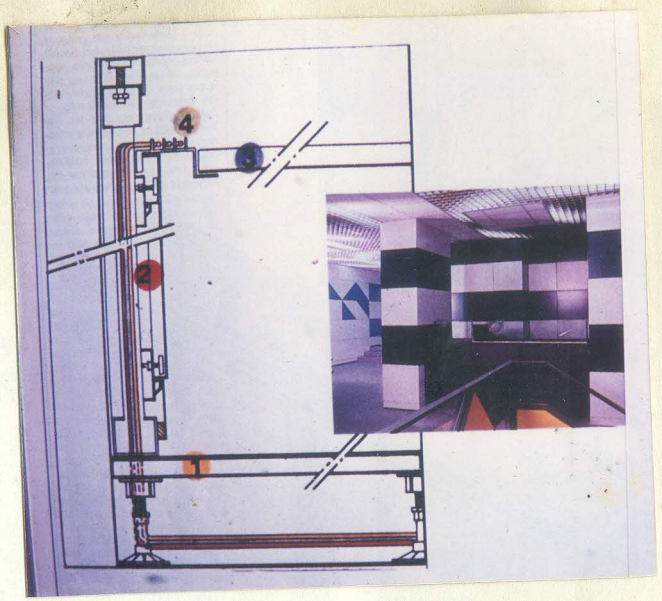
FURNITURE ↑

STORAGE ↑

APPLICATIONS OF MODULAR SYSTEMS

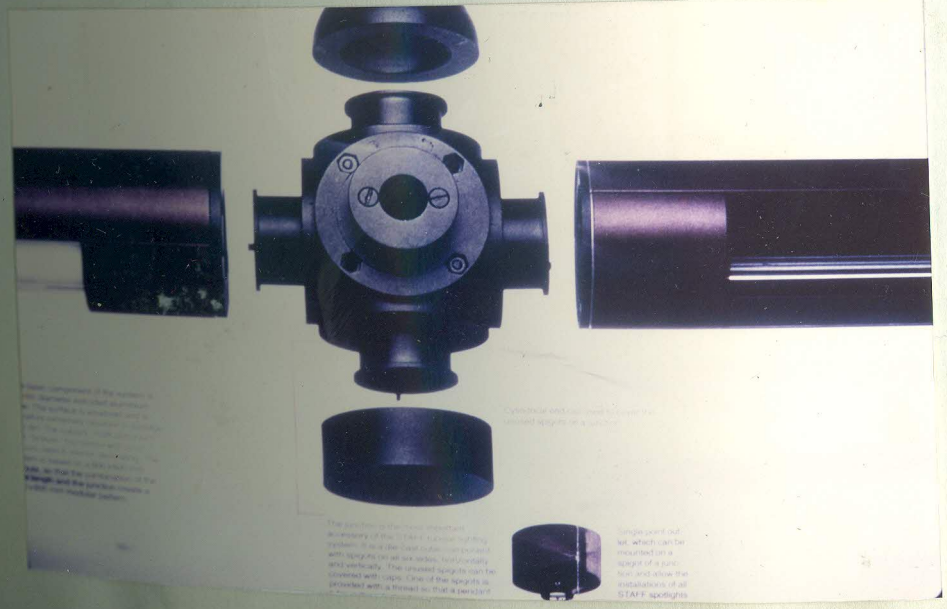


EXHIBITION DISPLAYS ↑



ACCESS WALLS ↑

LIGHTING ↓



FENCES ↓

PANEL JOINTS

Modular structures are being used more and more in furniture, partitioning systems, street furniture and outdoor shelters exhibition systems etc. All these applications emphasise on panels to be used as modules and hence panel joint is a subject of interest.

There are two methods of joining panels viz. panels as structural members and panels fitted on to the structure which is the load bearing element.

Panels as structural members:

The panels bearing all the loads are well explained in case of monocoque car bodies. In such a case the no. of elements is reduced and a light weight construction is possible . In such case,

- Panel to panel joint has to be designed so that it transfers all the forces including torsion from one panel to another.

- The panel material should be strong in all stresses i..e. shear, tensile, torsion and even skin strength.

- While building the structure, there is no support for modules till a stable formation is done Hence it may be necessary to use some temporary jigs etc. or design the assembly procedure in such a way that it allows the initial stable structure to be formed easily. One more disadvantage could be that the joints may be subjected to temporary loads which they are not designed for during the service.

Panel fitted to structural members

In this case the load bearing elements are assembled first and the panels are used only for cladding. Hence the stress analysis is much more resolved and the joinery is made simpler. There is also more freedom in panel material selection due to there independence from stresses

In case of outdoor structures more freedom is possible for solving the problems of waterproofing. Larger tolerances are possible because one panel does not affect the fixing f another.

Two theories of panel joining

Depending on the material of the panel, two basic ways of joint design can be prominently noticed viz. wood or bulk theory b) Sheet metal or thin sheet theory

a) In case of material like wood which has enough thickness which can provide a surface perpendicular to the panel surface in the joint zone that helps in supporting the joinery element e.g. if a screw is used to hold the panel there is enough bulk to tighten the threads. All wood working joints make use of the bulk of the part.

b) The other case is of sheet metal joints in which the thickness of the elements to be joined is so less that they are very difficult to join in built hence a lap is used with rivets etc. Also forming of edges is possible.

One more limitation with thin panels is that the joint elements can not be placed inside the panel like in wood and has to hold the panel from outside.

Joining of FRP panels:

There are two types of FRP panels viz. single thin panel and sandwich type thick panels where two FRP sheets enclose a filler material like foamed pu or honey comb.

- Since maintaining very tight tolerances is difficult in FRP the panels are preferably used as cladding rather than structural members.
- Different materials like wood or metal can be used for structure but enough adjustability is to be given for differential expansion of FRP and metal.
- If a joint element causes localized stress on FRP then there is a chance of crack formation. FRP panel edges can be formed to allow many possibilities for joint design.
- Combination of some other material like metal strips or even

injection moulded plastic parts with FRP is possible by adding them when panel s n green state.

Joining Principles and Mechanisms

In case of removable joints for holding two pieces together, various forces and mechanisms are used which keep the pieces in place. The mechanism can be decided depending on the forces and other factors discussed earlier. These forces can be mechanical, magnetic gravity etc.

Wedge Principle
The most widely used basic principle of a wedge which gradually applies force in a direction. Perpendicular to the applied force. the reason being that the applied force can be less than the tightening force.

The wedge even if not used in its original form, it is converted into some suitable form. e.g. if it is converted into a helix the resultant is a screw or a thread which is the maximum exploited form in use. The other form is a spiral as used in the cam lock designed for particle boards.

Quick joints

Modular joints require some kind of a quick mechanism in order to reduce the assembly and knock down time. These quick joints can be added in three ways.

a) Integral: the joint element is a part of the module itself. e.g. in lego toys the interference fit is used for joining.

b) Semi integral : the joint elements are fixed to the module before assembly by screws, glue etc. and the quick mechanism is activated at assembly e.g. Velcro.

c) Independent : the joint element is an additional part which hold both the modules by quick mechanism e.g. friction clamps.

New methods possible for panel joining

The accompanying sketches show some different principles used for quick joint of panels possible.

Joints for Particle Board

METAL INSERT THREADED.

PLASTIC INSERT PLUG IN

Special joints are developed for particle board since common woodworking joints cannot be used in particle board due to lack of skin strength and screw holding capacity. Hence increasing the contact area for joint element is very important.

1. Metal Inserts : Insert is the simplest way of increasing the screw holding capacity. They become a part of one element (i.e. particle board) and provide higher skin strength for threaded joint element. The sketch shows a threaded type insert which has bigger threads on outer side and smaller pitched threads internally. A threaded type metal insert can be screwed in the particle board and a normal bolt can be put in it without damaging the board. This allows a number of fastning and removal of threads.

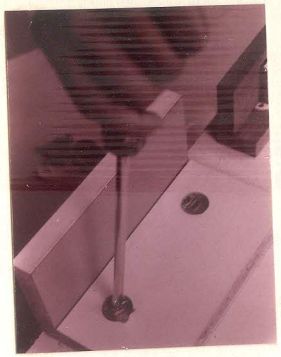
Plugin type inserts are also possible in plastic materials like nylon.

2. Barrel Nut : A barrel nut is used to further solve the problem of increasing surface area and alsomodular knockdown type joinary. the sketch shows the parts used in the joints. The pin goes into one panel from edge where as the barrel is inserted in the other panel from face. The grub screw holds the pin on fastening with an allen key.

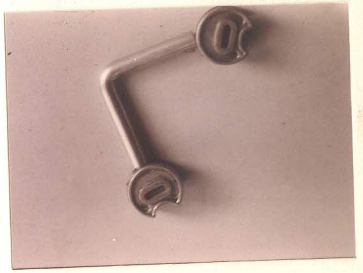
3.Camlock : This is a derivation of simple wedge principle by rotational motion The pin is inserted in one panel from edge or face with an insert. The pi is then grabbed by the wedge part which is inserted from face of the other panel.

CAM FASTNER FOR PARTICLEBOARD.

COMPONENTS OF CAMLOCK

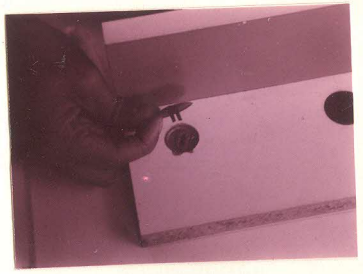


CAM GRABS THE PIN



CAMLOCK FOR MITRE.

PIN FITTED TO BOARD



PLASTIC CAP COVER

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