PDHonline Course C635 (1 PDH)

The Checkerboard Building System

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1.0 PROLOGUE

The Checkerboard Building System evolved and matured in the mind of a Jewish immigrant from Eastern Europe who came to the United States by the mid twentieth century via Israel. In the process he adjusted his name to get rid of its foreign sound and he ended up with identical first and last names. He claimed to be an engineer and a builder but nobody ever saw his credentials. He also claimed having prior extensive experience in prefabricated housing and nobody ever saw the evidence. However, he was witty and did have a quick, inquisitive and daring mind and a peculiar overriding personality. The author can attest to that by his own experience.

He was a self proclaimed expert in Graphology and nobody ever got to work with and for him without first having passed a graphological test and analysis. After completing his analysis he would conclude the process by telling the applicant all his findings about his or her character, personality traits, weaknesses and physical shortcomings. He had a quick eye for selecting the right people to fit into his entrepreneurial mind framework, and once in they had little choice but work for him like slaves, not by forcibly imposition but by having to follow his example of "do as I do" vociferous characteristics.

He was fiercely private, introverted, very dedicated to his convictions and knew nothing else but work as the centerpiece of his existence. He had an only child, a son who inherited only one of his poor qualities, his petulance, but was never able to measure up to the others.

In the 1960's when the Department of Housing and Urban Development (HUD) decided to implement its Operation Breakthrough, his building system was selected as one of the twenty-two winners and under that program he was given the opportunity to build a large number of housing units in Jersey City, New Jersey and Rio Piedras, Puerto Rico. He had the golden opportunity to excel in the housing market, however, for some unknown reasons it seemed that the United States of America was not ready yet for the challenge posed by the prefabrication idea. Although we must say that the Operation Breakthrough did achieve its political purpose and agenda but did not leave an enduring legacy nor created the needed momentum to have launched the idea as needed.

2.0 THE HOUSING NEEDS PARADOX

There is a considerable shortage of low income housing everywhere in the world, in fact there has always been. Naturally, considering the economic slump we are living in today, more housing does not seem to be one of the political priorities on the table. If we judge by what is taking place in the United States, there is in fact a surplus in the housing market. Due to the fall in the earning capacity of the breadwinners, families have started a process of compaction, either the kids have moved back with their parents, or vice versa. The larger the household becomes, the more efficient is the home economics for the purpose of survival.

Yet, when we look at the similar situation elsewhere in the world, in countries where economic contraction has been the norm rather than the exception, family compaction is no longer an option because the families are already compacted to the maximum. That is the paradox and therefore in the land of eternal economic slump where the housing crisis has always been present, transient economic ups and downs do not make any difference. That is the paradoxical relativity of the housing needs.

Modular building systems as part of the industrialized mass production has failed up to this point for three identifiable reasons that are interconnected:

a. Ignorance. Most people, as they are called “low information members of the society” are too fast in judging new ideas without having the proper understanding of the matter at hand.

b. Conservatism. There is a resistance to accept any solution that challenges the well rooted conventional ideas.

c. Politics. Politicians become the problem when they sense new ideas do not appear to bring together the masses of low information voters.

The point of beginning merges with the ending and both become one in an eternal vicious circle.

Other factors that need a full understanding for a modular system to be successfully accepted are these:

COST SAVINGS

The first reason to adopt an industrialized housing system is to reduce the cost of housing, and thereby to increase the number of units that can be provided with the budget available. The world has a need for more housing for families that cannot afford them from the private sector. Therefore, industrialized methods which can produce affordable housing are essential to fulfill that need. This is specially critical in places where funds are restricted or in other places where conventional construction could provide affordable housing but not in sufficient numbers.

The ability of an industrialized system to produce units at a lower cost may represent a combination of several factors such as, faster completion of tasks, better control of materials and quality control, easier supervision of labor, higher productivity, more efficient management, amongst many others.

Initially, the upfront costs of factory installation such as start-up costs, initial investment on equipment and materials, personnel training costs and working capital need to be considered very seriously. Those early costs will likely be much higher than in the conventional construction, however, as the system finds its way into an operating routine those costs should decrease substantially.

SOURCE OF STEADY EMPLOYMENT

The traditional shortcoming of conventional construction is its nature of transient source of employment for workers. A construction project starts and everybody involved knows that their employment will be terminated upon completion. That problem is essentially inexistent in an industrialized system where the objective is not only to produce units in a mass basis, but in order to amortize the initial investment a plan of continuity is vital for such an operation and therefore has a better chance of a continuing production trend.

TIME SAVINGS

It is a well conceived reasoning that faster production and erection of units allows available construction funds to be recycled more rapidly and the returns to be used to produce more units. At the same time, faster production also decreases the cost of interest paid for construction financing, thus further reducing the overall costs.

THE BEST MATERIAL

Any criteria used as a base to determine the best material would have to be a combination of several considerations:

Firstly, the chosen material must have to meet the structural requirements imposed by the governing code standards. It should be able to maintain an acceptable level of performance under adverse conditions such as fire and conflagration. Furthermore, such material must be able to reduce its cost of maintenance and be available in abundance and at a reasonably low cost. It should be resistant to insect attack and have adequate low sound and heat transmission.

One of the remarkable achievements of Operation Breakthrough was the opportunity it offered to the participants to try a diversity of materials such as: wood, steel, aluminum, paper, fiberglass, fiber-reinforced plastics, cement-asbestos, polyurethane and concrete.

After having seen, evaluating and comparing all those materials, there was no doubt that steel reinforced concrete was by far the superior material to be used on any serious industrialized housing system built to endure all odds and perils.

3.0 STRUCTURAL DESIGN PRINCIPLES

The two traditionally prevailing schools of design (flexibility vs. rigidity) which have been in eternal confrontation for over two centuries may have now reached a winning compromise to settle once and for all their arguments and differences. Concrete is indeed a rigid material that tends to produce and develop rigid structural systems when used following the precepts of conventional construction. However, when rigid modular concrete boxes are used, they may be erected together in such a way that rather than achieving the typical concrete to concrete joints, *neoprene pads* are placed in between the concrete surfaces and additionally, the module boxes get "threaded" together with a vertically oriented post-tensioning system. By doing such an arrangement, the concept converts from a rigid to a flexible structural system with a high degree of ductility to behave in a virtually indestructible way against the most exacerbating lateral loads coming from earthquakes, hurricanes, tornadoes or even man-made events such as nuclear blasts.

4.0 DESCRIPTION OF THE FEATURED SYSTEM

The central piece and heart of the system consisted of an eight-hundred and fifty square feet prefabricated concrete module box, as depicted on Figure 4.1, with two "horns" on the frontal upper part of the box, which were in fact two projecting cantilevering beams with the purpose of providing support for the corridor slabs on one side for a "single loaded" arrangement or on both sides for a "double loaded" design.

The boxes were stacked in a checkerboard pattern with a one foot overlap, in such a way that there was a gained space in between two consecutive boxes. Within the overlapping zone there were vertically aligning columns (Figure 4.2) that took the gravity loads all the way down to a conventional (or precast) foundation system designed to accommodate the bearing capacity of the local soil conditions.

In addition to the checkerboard pattern which was well noticeable from its elevation view. The inventors also added an optional variant by setting back or forward the boxes in such a way that the apartments gained front and back balconies and porches for all the units in the cluster. This was indeed quite an interesting modality with a clever tri-dimensional twist to the original checkerboard lay-out. The price that had to be paid for this feature was the boxes having to be cantilevered some six feet, an extra pair of columns had to be added, and last, the lateral load moment resisting capacity was reduced, thus also reducing the practical building attainable height from a maximum estimated twenty-two stories down to some ten stories, provided the module box size was kept as a constant parameter.

In order to keep the box weight within reasonable lifting limits, both floor and roof slabs were kept to a maximum thickness of 3½ inches. To achieve such a goal, it was necessary for the design engineer to use some of the interior partitions as concrete bearing walls and/or inverted beams.

Integrally cast in customized steel molds, the concrete reached its maximum density by shaking the mold rather than introducing vibrating devices into the fresh concrete mix. Immediately after the pouring was complete the box was then confined for a few hours in a steam chamber for accelerated curing.

Depending on the building purpose, the hoisting devices available at the site, and to whether it was for a low-rise or a high-rise application, the concrete mix to be used could have been either regular weight, lightweight or foam concrete.

Once the unit was adequately cured and the concrete attained its minimum required strength, the box was stripped out of the mold and the gantry moved it to the finishing line where the box was furnished with all its required hardware, harnesses, fixtures, cabinetwork and appurtenances. When all those trades had finished their tasks, the unit was cleaned-up, painted, inspected and sealed.

Every module box was then transported to the site where it was lifted to position until it was its turn for the residual field work to be done. Unlike the other systems described on some of our courses where boxes were stacked one-on-one and one-next-to-the-other arrangement, on this featured checkerboard pattern system there is a substantially larger amount of field work to be done.

Although the factory finished unit normally containing three bedrooms with their respective closets, two bathrooms and a finished kitchen was complete and ready to be used, the gained space where the living and dining rooms were, needed to be field assembled and finished. As a natural result of the arrangement, a 4 in. step down between the bedroom area and the living room area may have been seen by many as an inconvenience, however, the amount of work that would have been necessary to avoid it may not have been worth the effort. On the other hand, the gained spaces at the top of the stack needed to be covered with a prefabricated roof and the end gained bays also needed to be enclosed with prefabricated end-walls (Figure 4.3). In some cases the end wall could have been avoided if the architectural design of the building was made in such a way that the building ends were conceived in a stepped down fashion.

Overlapping columns were provided with 1½ to 2 in. cast-in-place thin walled tubing which allowed the insertion of post-tensioning bars. Once those bars were pulled to the prescribed tension force and were adequately grouted through the grouting ports as provided at strategic locations, the system became integrated and able to resist lateral loads of high magnitude.

As indicated above, during erection, a designed 12 x 12 in. neoprene pad (or larger depending on column size) with a minimum thickness of ¼" was inserted at the horizontal joint in between columns. The combination of inherent flexibility of the post-tensioning system and the relative damping effect of the neoprene (Figure 4.3) would bring about a maximum ductility system able to handle unanticipated stress concentrations under extreme transient loadings, uncommon deformations due to high temperature changes and even unexpected foundation differential settlements.

Prefabricated corridor slabs were then erected in place over the cantilevering beams provided on the front of the boxes. The system allowed for "single or double loaded" architectural building designs. Prefabricated elevator boxes as well as prefabricated stairs were also produced in the prefabrication plant, transported to the site and erected as necessary to solve the building's vertical transportation and access needs.

The "universal box design" provided enough flexibility to allow its use for either tropical or tempered climates, however, the latter required a somewhat larger module box to accommodate application of additional insulation as well as the extra components necessary for an effective heating system.

To prevent rainwater seeping in and down through the multiple joints in the system, joint waterproofing was an important task to maintain the necessary and expected water tightness. Therefore, joints needed to be adequately sealed either by means of a vinyl "rope" or a self-adhesive sponge-rubber tape.

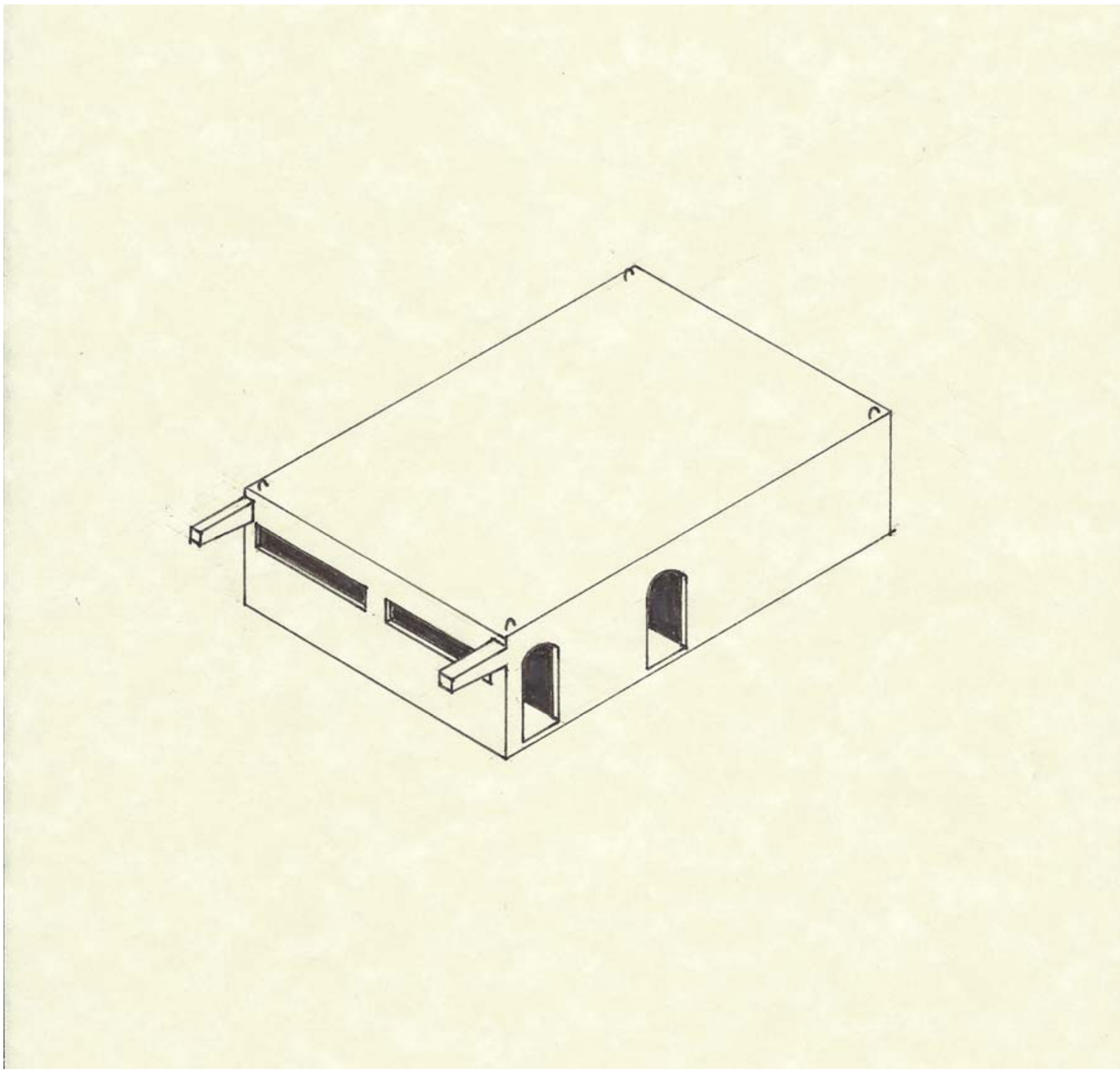
Another anticipatory provision built in this system was the use of safety grip nuts. If the erection process was ever interrupted, whether it was for a long holiday weekend or in case the area was under hurricane warning, those grip nuts once properly engaged (see Figure 4.4) would provide the required stability to the system for as long as it was deemed necessary. Those same grip nuts could also be used as a final and top anchorage for the post-tensioning bars at the roof level.

When it came to anchorage at the lowest point of the post-tensioning system, it was done with a combination of grip nuts and anchor plates carefully secured, aligned and cast as part of the foundation system.

Figures 4.5 and 4.6 graphically depict the post-tensioning hardware components that were necessary to make the system work in an effective manner. For practical reasons the post-tensioning bars (rods) had to be spliced at every floor and for that purpose a 6 in. coupler had to be provided as shown on those figures. To make room for the couplers in their upwards traveling due to elongation of the post-tensioning bars, an enlarged tubing area had to be provided accordingly.

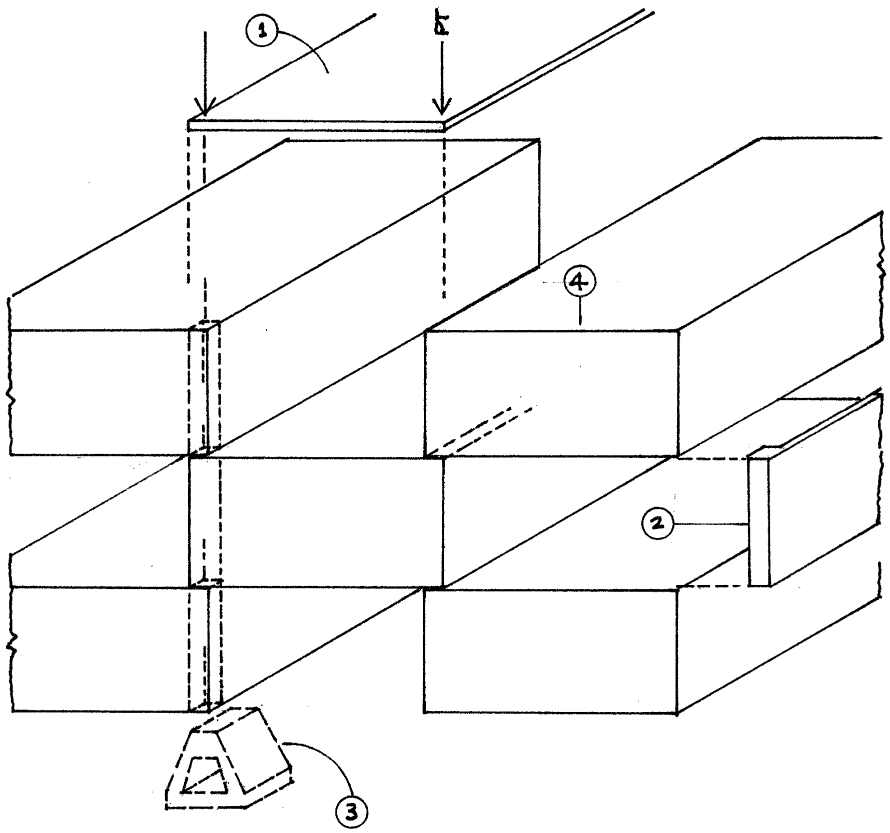
Grouting was also an important part of the process, for it provided two functions, first an added anchorage to the post-tensioning bars and second, embedment protection against deterioration. In order to fully accomplish those purposes it was necessary to ascertain that no air pockets were left behind in any part of the tubing.

After the post-tensioning was complete, secured with the upper grip nut, tested and the excess post-tensioning bar cut slightly over the grip nut, the grouting task would start by pressure flushing the entire duct from the lowest point with clean water, then the grouting mix (basically cement, clean water and an approved plasticizer) was injected from the bottom up and from every other floor until the mix would pour out clean at the uppermost level. The following day, all grip nut locations were thoroughly cleaned up, formed and capped up by using a previously approved chloride free concrete mix.



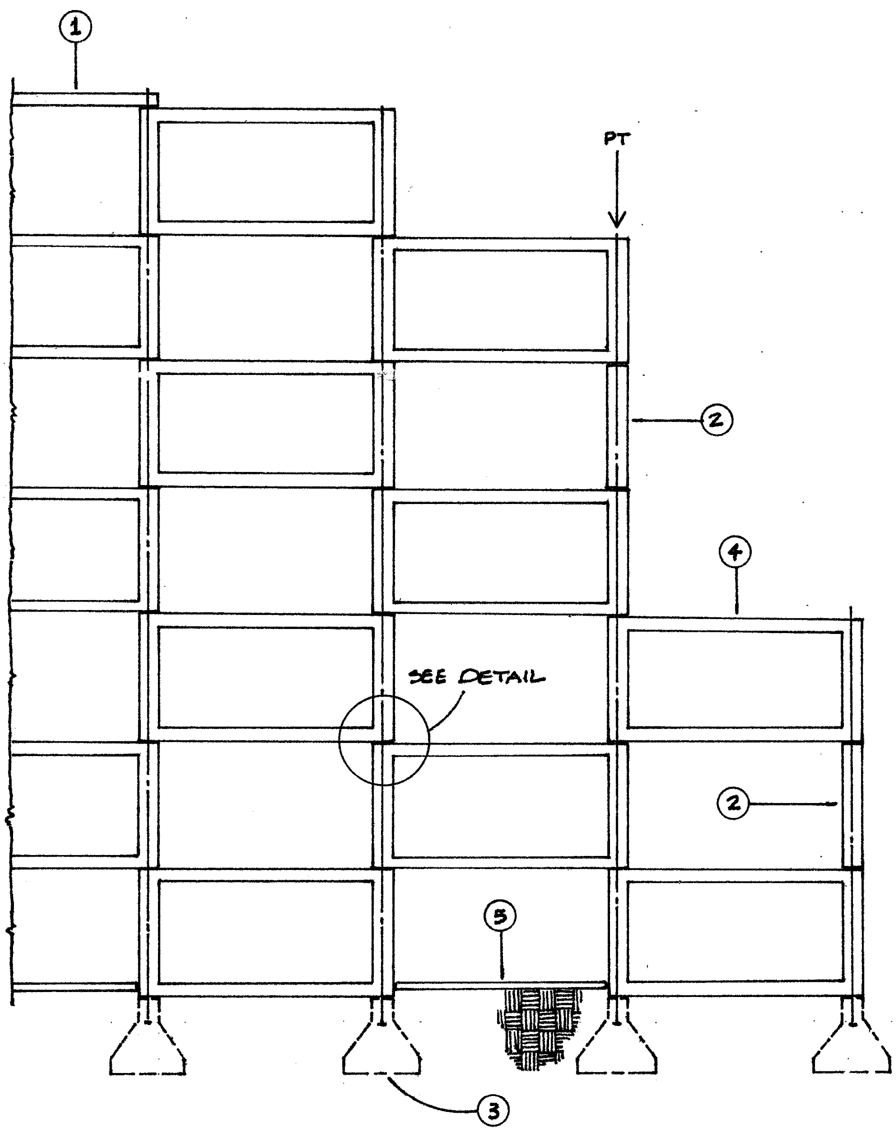
Isometric view of the module box

Figure 4.1

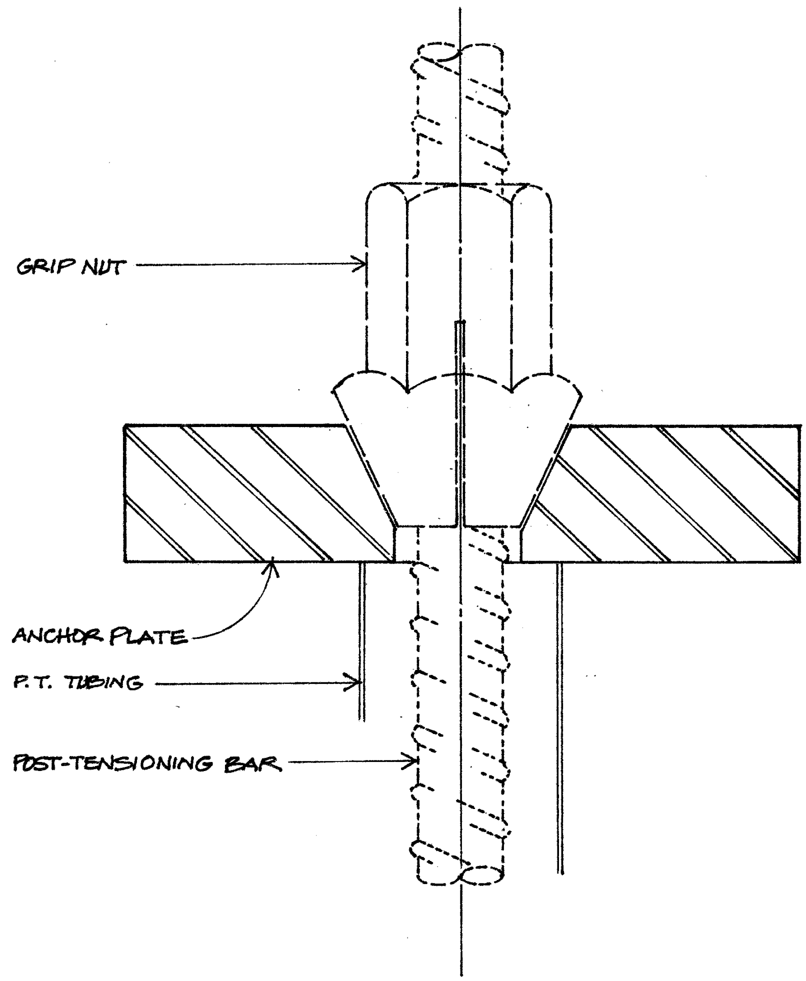


1- Precast slab to cover gained space.
2- Precast end wall to enclose gained space.
3- Conventional or precast foundation.
4- Typical concrete box.
5- Slab on ground.
(Above key numbers also apply to the following Figure 4.3)

Isometric view of the building system
Figure 4.2



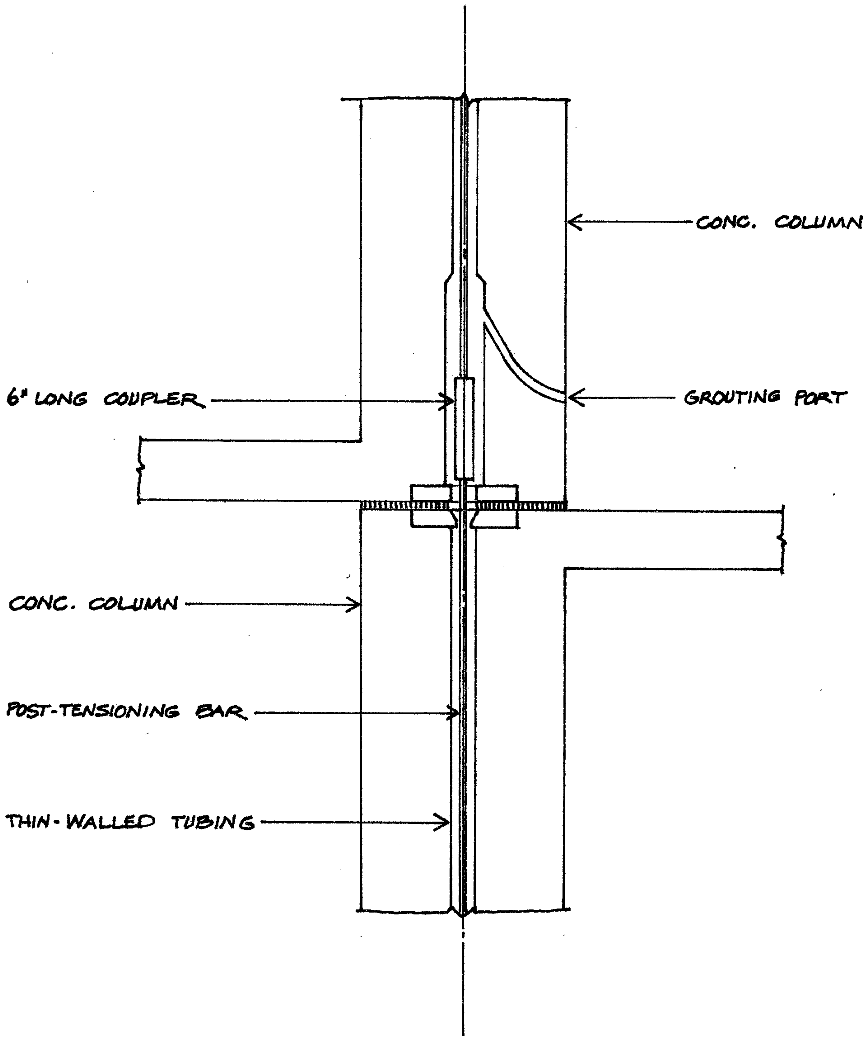
Frontal view of the building system
Figure 4.3



Typical grip nut detail

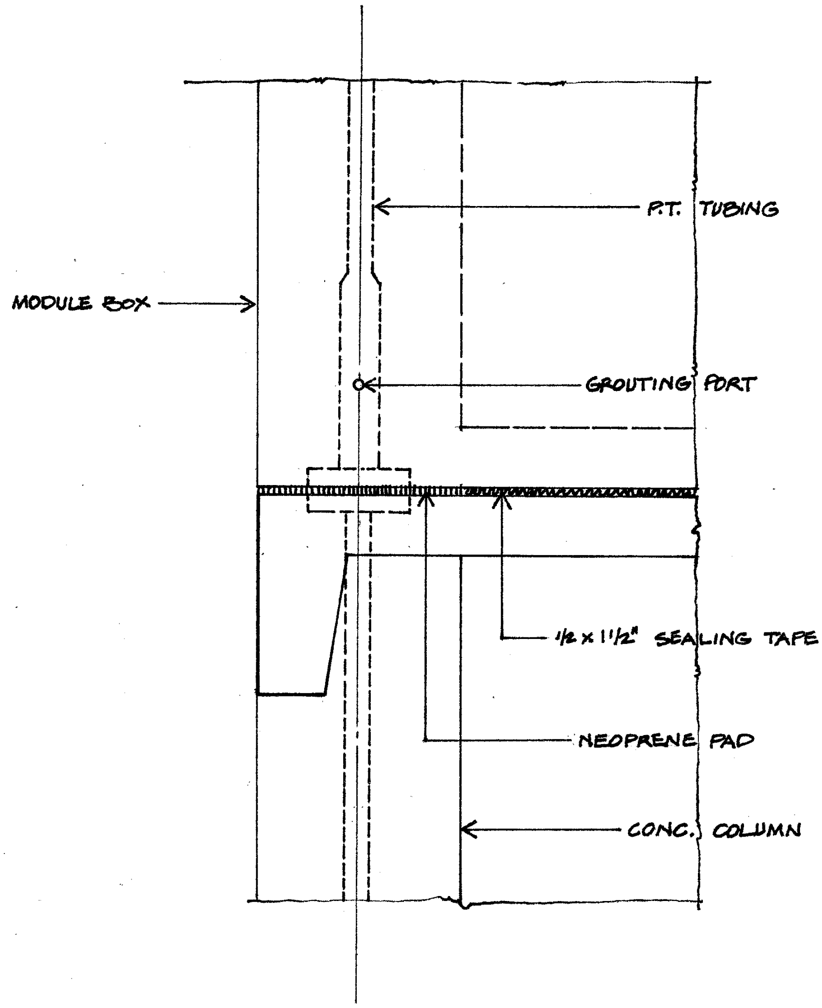
(Slit shown in front of the nut facilitates full engagement when bar is under tension)

Figure 4.4



Front view of the post-tensioning system

Figure 4.5



Lateral view of the post-tensioning system

Figure 4.6

5.0 CONCLUSIONS

The Checkerboard Building System as described in this course, although effectively avoiding the duplication of walls and floors that takes place in other systems such as the one described in our course titled “Prefabrication: An Unfulfilled Promise“, does have the drawback of a large amount of residual work left out for the field crews to perform. However, in spite of such limitation, it is fair to say that its advantages by far surpass its shortcomings and consequently, we must say that the Checkerboard Building System is one of the best systems which have been conceived in the last one-hundred years of prefabrication history.

Before closing, a last word of caution and wisdom seems to be appropriate. Necessary for the development and growth of industrialized building construction is the creation of an institute for the continuing research of new applications and laboratory testing of new materials as well as those currently in use. Such research is particularly critical as the private industry is too fragmented and without the necessary financial resources, nor can it be dispassionate enough when making comparisons on the general performance of market systems and materials. Furthermore, private companies are traditionally more concerned, and rightfully so, with protecting and improving their own products and proprietary designs than trying to share their knowledge and technology for the common benefit of the industry at large.

Consequently, further to HUD’s initiative of the 1960’s, the government does have an unavoidable role and responsibility to lead by example, as well as to establish the ground rules for everybody in the industry to follow and have an equal opportunity to grow and flourish.

END