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Unconventional Construction Methods

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1.0 Introduction

The decades of the 1960's and 1970's defined a period in the U.S. history when the market was flooded with an influx of methods and ideas never seen before. It could probably be designated as the largest growth and advance ever experienced in the construction industry.

Initiatives such as Operation Breakthrough lunched by the U.S. Department of Housing and Urban Development (HUD) in the late 60's brought and onslaught of the best ideas, amongst others: Moshe Safdie's Habitat, S. W. Shelly's Vivienda 70 and H. B. Zachry's Palacio del Rio. In the same way, it also attracted the best minds of the time such as: T. Y. Lin, Edward Rice, Andrew Gyimesi, and August Komendant, just to mention a few.

According to the statements made by the then HUD's Secretary George Romney, Operation Breakthrough was "an experimental program guided to take the housing industry out of the field and put it on the factory assembly line". That would indeed had been a great shift for an industry which had always been the Cinderella of all industries, and would have provided a dependable and steady job inventory where there had been none. He added that the program was also intended to be "a catalyst to change the focus of the industry from conventional stick construction to volume production".

Interestingly enough, some of those ideas endured the test of time and some other ones faded into obscurity either for their own flaws, for the lack of political acceptance or in other cases because although plausible, their timing of inception in the market was poorly unveiled.

It is regrettable that our present economic slump is a poor environment to promote new ideas, however, we need to see the problem from a factual and realistic point of view, the construction industry has always been slow to react to the fluctuations of the market and the economic trend changes. Therefore, we must get ready in anticipation of the change for the better which is quite likely ahead of us.

In this course we will review those ideas on their merits and they will be presented to you as they have been updated and /or have evolved to meet present day code requirements or, as they have been improved to catch up with the prevailing market conditions.

2.0 Overcoming Concrete Cracks

As indicated and affirmed in some other of our listed courses, concrete is a superior construction material known for its availability, moldability, predictability, durability, strength, fire resistance, decay resistance and its immunity to insect attacks (termites included). However, one shortcoming stands high amongst its few drawbacks, and that is its propensity to crack. That cracking susceptibility is directly connected to shrinkage and temperature differentials. In this section we will address the available solutions to the former.

Immediately after pouring concrete a chemical reaction is unleashed, concrete starts to lose water and to shrink, if that loss takes place too fast the resulting shrinkage subjects the concrete mass to tensile stresses that the fresh concrete has no strength to resist and consequently it cracks. If we keep the concrete well saturated with water, the process of cracking can be greatly reduced although not entirely resolved. Therefore, logic dictates that if we add an agent to the concrete mix that cancels out that shrinkage, we would be on our way to overcome cracking due to shrinkage. Further, if that added agent would have the capacity not only of overcoming the shrinkage, but reversing it with a remaining elongation effect, then we would be assured of producing a concrete which would be crack free from that end of the equation.

Such agent (or admixture) does exist and in fact has existed since the early 1960's. Generically is known as *expansive cement* and potentially can produce a non-cracking concrete. The vital ingredient in such admixture is *calcium sulfo-aluminate.* For those of you interested in the formula, here it is: $3CaO\text{-}Al_2O_3\text{-}CaSO_4\text{-}31H_2O$. This formulation is accompanied by an increase in absolute volume and therefore creates a net expansion. Concrete mixed and produced with such an additive (at a price) is likely to yield a crack resistant concrete that expands as it sets. Although we will not use this media to divulge or promote trade names, that admixture has already been widely tested and produced by companies such as: Dow Chemical Co., Du Pont De Nemours and McKesson & Robbins.

One word of caution is in order here. According to tests and studies performed at the Alcoa Research Laboratories, it has been found that when aluminum (anodic material) and steel (cathodic metal) are embedded in concrete, if there is also presence of chlorides, a galvanic current will develop thus accelerating corrosion and therefore developing in the concrete what we are trying to avoid: cracks. Noticeably, the second term on the above formula for the admixture is *aluminum oxide.* Consequently, it is important that chloride-free concrete is specified by the design engineer or architect, and its use verified by the field inspector. If unattainable, then, all metals should be coated with epoxy paint to avoid the development of galvanic corrosion and ultimately concrete cracks.

Enclosed Figure 2.1 shows a graph comparing typical 5½ bags per cubic yard Portland cement concrete with an ultimate compressive strength of 4,000 PSI, versus a similar expansive cement concrete. The graph consists of a time related expansion/contraction curve plotted for a period of 300 days from casting. The zero line represents no volumetric changes, while the positive values above the zero line represent expansions and the negative values below such line represent contractions.

Bear in mind that adding such an admixture to your concrete can also add to your unit cost at the rate of some $20-30 per cubic yard, depending on the degree of detail involvement. However, the benefits can be translated into significant savings in time, material, equipment and labor as compared to those where conventional mixes are used. In the last instance, the positive balances for the user are: much less jointery, less cracks, and less maintenance during the life of the structure.

When it comes to the engineering design practice, both the flexural strength and the modulus of elasticity are similar enough on both concretes to call them the same. On the other hand, bond strength is somewhat higher in the expansive concrete than in the regular concrete, which is beneficial. Some of the construction practices related to shrinkage need some adjusting on the advantageous side, for instance, the need for checkerboard pouring pattern and the saw-cut joints can be completely eliminated.

Finally, there is a reasoning attached to the use of this material that is important to remember: as the expansive concrete mix is poured and cured over the reinforcing cage, it gets bonded to the reinforcing bars with the resulting pull effect on them as it expands. The expansion is restrained by the reinforcing steel, and in turn the steel is placed in tension. As the steel gets under tension, the expansive concrete gets under compression, which is the opposite of what occurs in the regular Portland cement concrete. This translates to a net pre-stressing gain in the concrete, which is produced for free, meaning without the normal cost of material, labor and pre-stressing equipment.

To those of the readers who wish to know more about expansive cements, there is a great deal of information which can be obtained from the description sheet of existing related patents, both lapsed and active. If this is the case, you may proceed to examine U.S. Patent Nos. 3,785,844; 3,883,361; 3,884,710 and 4,002,483.

FIELD APPLICATIONS

There are many applications worth mentioning, where expansive cement concrete was successfully used because of its superior qualities and advantages, here are a few of them:

1. O’Hare International Airport, Chicago, Illinois. The world’s largest concrete parking structure with a whopping total of 120,000 cubic yards of expansive cement concrete. A six level facility designed to accommodate 10,000 automobiles. By combining the benefits of the post-tensioning system and the expansive cement concrete, C. F. Murphy & Associates, Architects-Engineers were able to materialize a sound project which has provided low maintenance service for over forty five years.

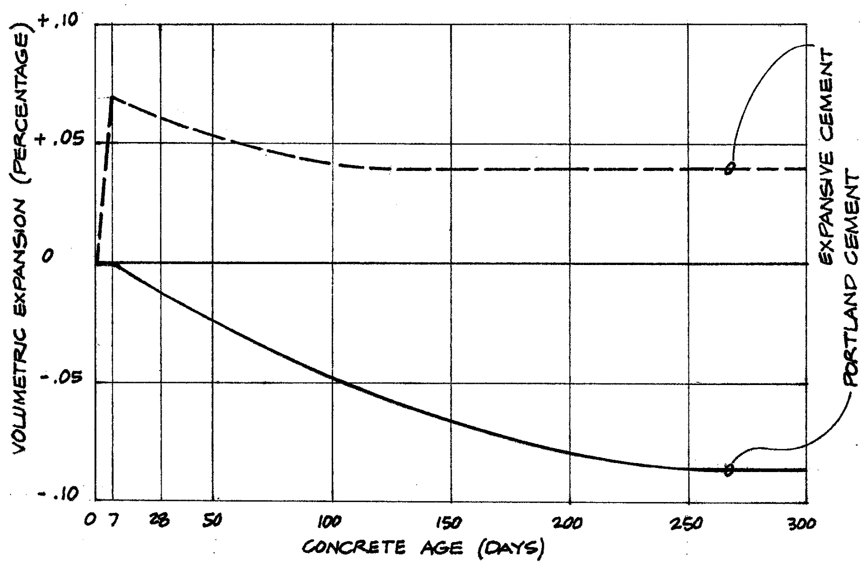
2. Dallas International Airport, Dallas, Texas. A three lane 75 feet wide by 5,300 feet long taxiway designed to provide a suitable and stable pavement for landings and take-offs of Boeing 727 jets. The design prepared by Forrest & Cotton, Engineers called for the minimizing of expansion/contraction joints with the resulting 14 in. thick panels of 25 x 125 feet with no intermediate sub-joints. The results have been outstanding.

3. Stran-Steel industrial plant in Houston, Texas. The design prepared by Brown & Root, Engineers called for a total of 627,000 square feet of 6 in. concrete slab placed on well compacted sand fill and polyethylene moisture barrier. Expansion joints were provided at 180 feet intervals.

4. Garden State Arts Center, New Jersey. Since concrete curing cracks are an architect's worse nightmare. Architect Edward Durell Stone wished a concrete that was not only crack free but dimensionally stable. His engineer T. Y. Lin & Associates provided the answer for him. He recommended the use of expansive cement concrete, which became the perfect solution to do the job.

5. Fedco Department Store, Pasadena, California. 114,000 sq. ft. shopping area with an adjacent 112,000 sq. ft. parking garage structure suitable to accommodate 445 cars as designed by Architect Paul Williams, FAIA.

The success of the above projects has pointed to a new direction in crack free concrete technology, when the design engineer or architect needs not to be concerned with the phenomenon of shrinkage cracking.



Comparison of volume changes in expansive cement concrete vs. regular Portland cement concrete. The zero line represents no volumetric change.

FIGURE 2.1

3.0 Overcoming the Concrete Weight Woes

True that concrete sheer weight is a formidable allied when it comes to the structural design of hurricane resistant structures. However, those same 145 PCF which have to be carried before any consideration can be given to any other dead or live loads, may become an undue burden for the design engineer. While some amelioration can be had by using lightweight concrete with an approximate unit weight of 110 PCF, those savings are not enough when compared to other materials weight vs. strength ratios.

There is a solution which can cut that undesirable weight down to one-third and even to one-tenth. We are referring to the alternative offered by the *foam concrete.* Foam concretes have been around for over fifty years and despite the fact their qualities have been exploited, exaggerated and deprecated, they still remain as a viable alternative when weight becomes the primary design issue.

The oldest known foam concrete came from Belgium and was extensively marketed in Europe and South America under the trade marked name of *Betocel.* Many of the materials which followed after were very much modeled after the Belgian product. Consequently, we will use Betocel as our herein descriptive role model.

The mix was made of coarse sand, Portland cement, water and a proprietary emulsifier. The resulting material was light enough to float on water, had great insulating qualities, relatively strong, resistant to cracking, fire and decay. By adjusting the amount of emulsifier in the mix the weight could be adjusted between 15 and 75 PCF. The same way the ultimate compressive strength could be adjusted from 70 up to 1,300 PSI.

In addition to being quite stable as a construction material, there were some other qualities that needed to be emphasized: it could be conveniently mixed at the jobsite and its panels could be hand sawed, drilled, notched and even nailed like a piece of wood.

Many buildings erected in Europe after the Second World War still stand in tribute to Betocel, one of those is the eight story Hilton Hotel in Istanbul, built entirely with that form of foam concrete (or cellular concrete as it was also called by its users).

Competitive materials with improved formulations have surged since then. An American company called Allied Foam Technologies (ATF) has developed a new foam concrete that allegedly can develop an ultimate compressive strength of 2,550 PSI with a material density of just 76 PCF.

Concomitantly, there are some other manufacturers presently engaged in producing a form of concrete which uses threaded expanded polystyrene as the principal form of aggregate. Beware that such products neither are comparable, do not fall under the same category of the foam concretes, nor are they endorsed or recommended.

4.0 Raising the Roof

Let us imagine for a moment that you are a business man who has the long time dream of opening up a superstore to sell your own line of merchandise. You have been lucky enough to find the ideal building, it is located right on the main drag of your own town, has good access for incoming traffic from both sides of the road, the parking is plentiful, it has the 20,000 SF you needed and the landlord is offering you a low monthly rent with a ten year lease with an option to buy the property at the end of the lease term. There is only one problem, it is an older building and the clear height is only 12 feet. But to best serve your purposes you must have 20 ft. clear height. Too bad, you may have to pass up the opportunity. But, before "throwing the towel" you decided to pay a visit to the most creative engineer in town and he told you: "nothing to worry about my dear Mr. Hutchinson, all you have to do is raise the roof"…..what? did I hear you correctly, raise the roof?, "yes, and this is how you do it" as he said that he held in his hands the picture of a certain device which we have marked as Figure 4.1 and you will find enclosed herein.

"You furnish every column in the building with a *power jack* immediately under the girder at one side of the column and follow the following instructions to the letter":

#1- In addition to the power jack, every column is also provided with a *sleeve* made out of four steel angles welded together with spacers. Such sleeves have been designed to match the same structural properties of the columns which they are going to partially replace.

#2- The sleeve is installed wrapping around the existing column. The column is partially cut at one foot above finished floor elevation; such cut is made through the open spaces in between the angles. Then, rotate the sleeve enough to expose the remaining uncut parts of the column.

#3- Weld the sleeve fully all around the column base. When the lifting is ready to start, cut the remaining part of the column in between the angles and let the weight fully rest on the power jack.

#4- All power jacks will rise at the same time and at the same rate, as they are controlled by a computerized synchronization system. The computer will adjust the lifting every time a jack has a deviation of more than one-eighth of an inch.

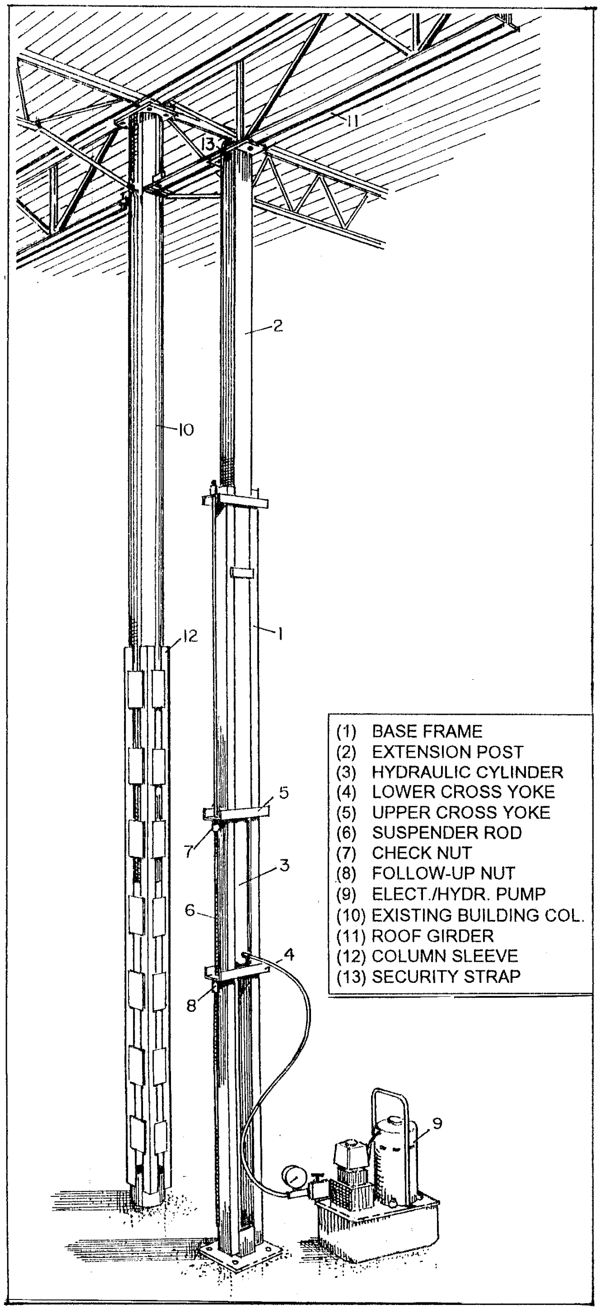
#5- At the perimeter, where the joists are bearing directly on the exterior walls, a temporary steel beam is tack-welded to the bottom chords of the joists about two feet away from the wall. The steel beam is also provided with pipe columns for temporary support.

#6- When the lifting process is complete to its final level, the top of the sleeve gets fully welded to the remaining upper part of the existing column and the power jack gets retrieved.

#7- Extend the exterior walls enough to provide new bearing plates for the joists. Once the joists are resting on their intended places, remove the temporary steel beam and columns.

All the remedial structural work is now complete, all that remains now is the cosmetic and residual work, such as small repairs, patch-up, painting, extending rain leaders, re-routing electrical wiring, extending air conditioning ductwork, general cleaning, etc. to be done by others.

What we have described above is based on one of the brilliant ideas as conceived in the spring of 1993 by our good friend and man for all seasons, the late Peter Martin Vanderklaauw, engineer-architect-inventor. He followed those same above described steps while raising the roof of a building to house the new headquarters of The Sports Authority (TSA) in Fort Lauderdale, Florida.



11
13
2
10
1
12
5
7
3
6
4
8
9
(1) BASE FRAME
(2) EXTENSION POST
(3) HYDRAULIC CYLINDER
(4) LOWER CROSS YOKE
(5) UPPER CROSS YOKE
(6) SUSPENDER ROD
(7) CHECK NUT
(8) FOLLOW-UP NUT
(9) ELECT./HYDR. PUMP
(10) EXISTING BUILDING COL.
(11) ROOF GIRDER
(12) COLUMN SLEEVE
(13) SECURITY STRAP

FIGURE 4.1

5.0 Promoting Safety at the Jobsite

Safety at the jobsite should always be an important item in the agenda of an experienced all-around builder. Accidents at the construction job can be very disrupting and very costly; therefore, they must be avoided at all cost.

The steps to be taken are well known, here are a few of them, but not necessarily limited to:

- Every jobsite of any importance should have a properly trained and certified safety officer who sees that all the requirements are met.
- There must be a safety program in place and workers should be trained to become part of the solution.
- Construction jobs, especially hi-rises, should be equipped with the proper features to prevent accidents (such as safety railings) and protect against perilous falls (such as safety nets).
- All workers shall wear protective gears, such as adequate helmets, cladded shoes and heavy shirts.

Figure 5.1 shows an activity that despite of all of the efforts to enhance safety still is being practiced at present times. Because of the predominance of the load, that practice may put the worker in serious jeopardy and increase the possibility of a fall, therefore it must be avoided.

The solution to prevent such a scene is depicted on Figure 5.2 with the use of a simple but clever French contraption called *le boomerang,* which should be made available in every responsibly managed multistoried building construction. This device has eccentric components and rollers, and as it goes through steps 1, 2 and 3 which allows one of the legs to enter the building and deliver or pick up the load in a manner that is safe for the workers to handle. The enclosed drawing is self explanatory enough, and that makes any further description redundant.

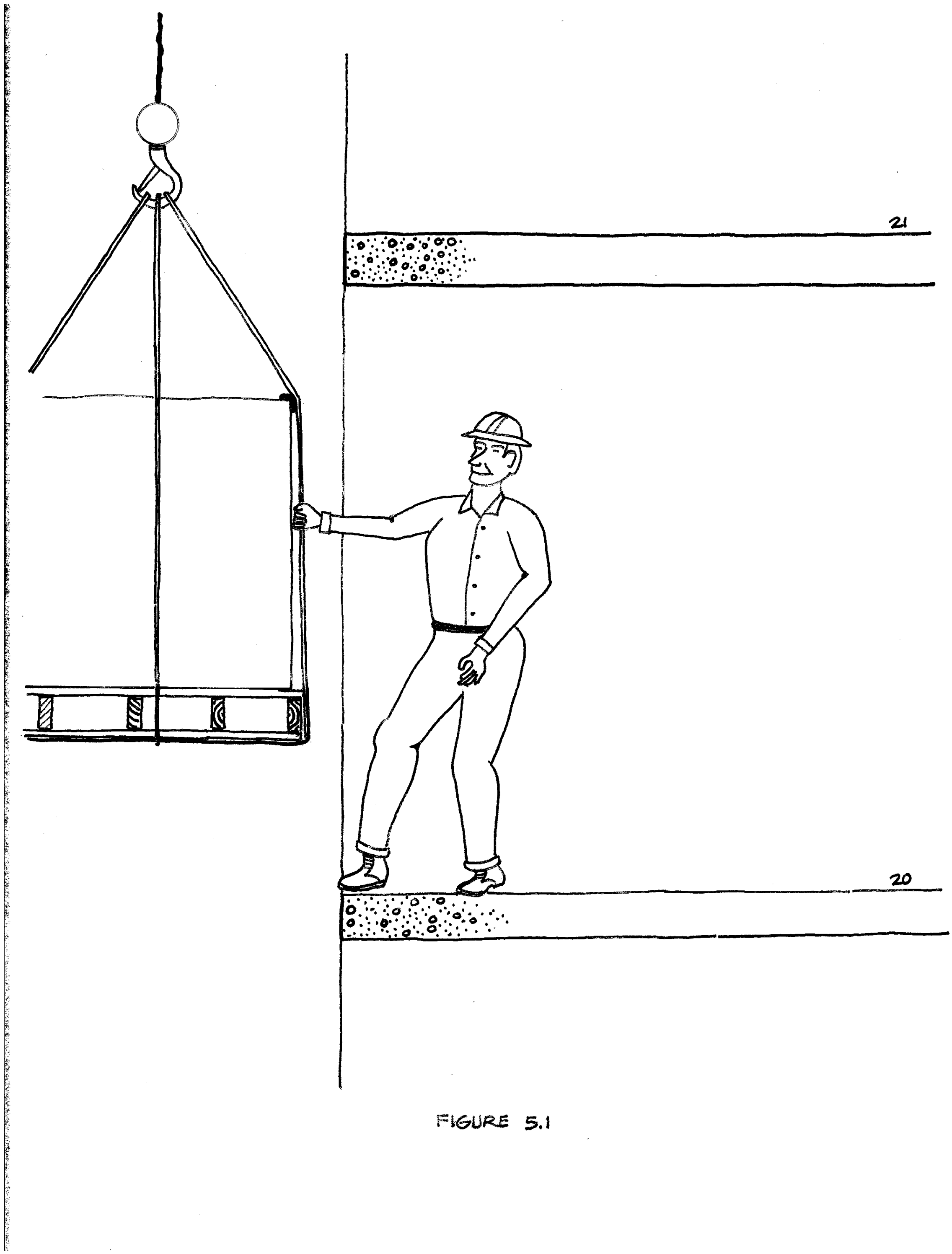
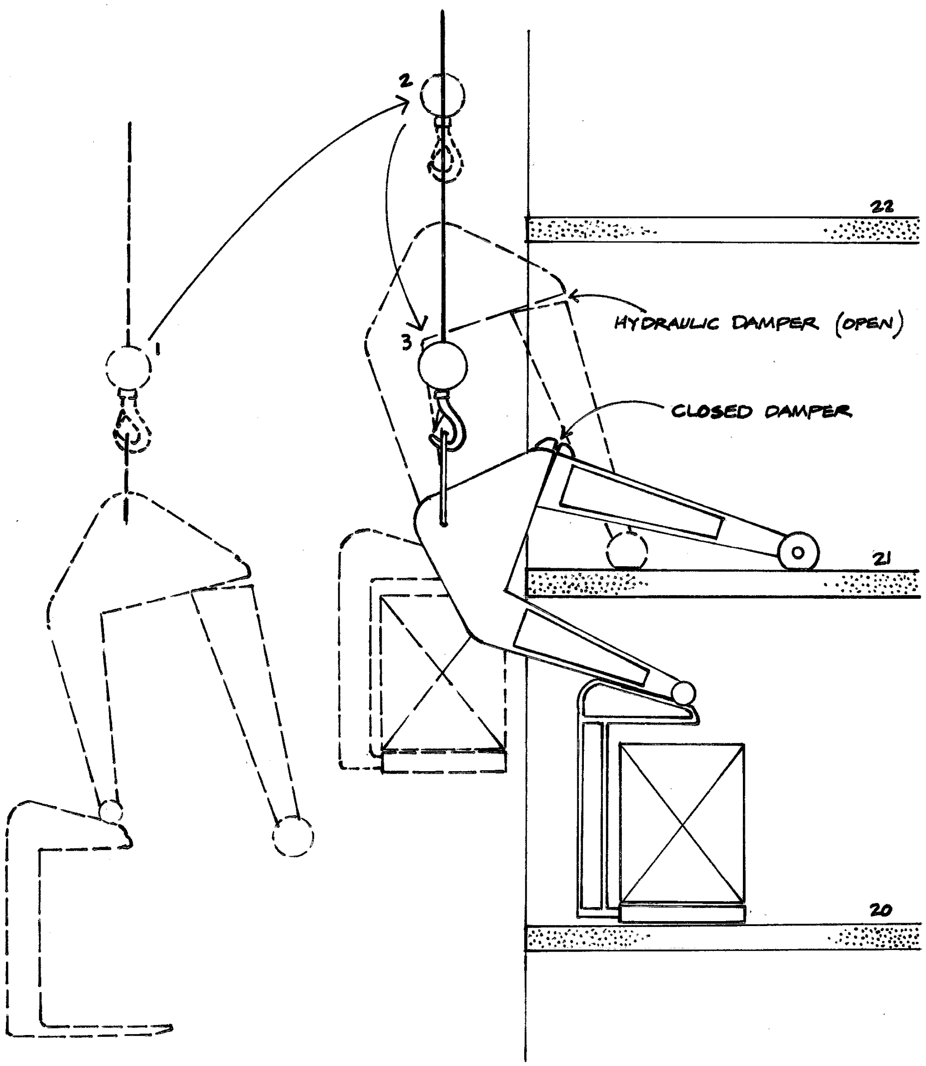


FIGURE 5.1



LE BOOMERANG
FIGURE 5.2

6.0 The Lift-Slab Method (LSM)

This method of construction has been around for over forty years and is well proven. It basically consists of flat slabs poured at ground level on top of each other in a "layer cake" modality. The second floor is down below and over the slab on ground, and the roof slab is the last one on top. Normally the pouring pace is at the rate of one slab per week. To prevent the slabs from adhering to each other, a bond breaking compound is applied before the reinforcement installation begins.

Shearheads are provided at every column and are cast in the concrete. They are also furnished with a steel collar and two sets of steel studs within an open space, in such a way to facilitate access to the lifting hooks which are dropped down to pick up the slabs to be lifted. Those collars also make possible the installation of leveling wedges as the slab gets welded in its final position. Figure 6.1 shows one of the shearhead designs used by the author as well as a picture depicting a shearhead which had already been cast in the concrete slab, and later leveled, wedged and welded in place.

SHEARHEAD COMPONENTS

Since the shearheads are such an important part of the Lift-Slab Method, we found it appropriate to describe them in more detail:

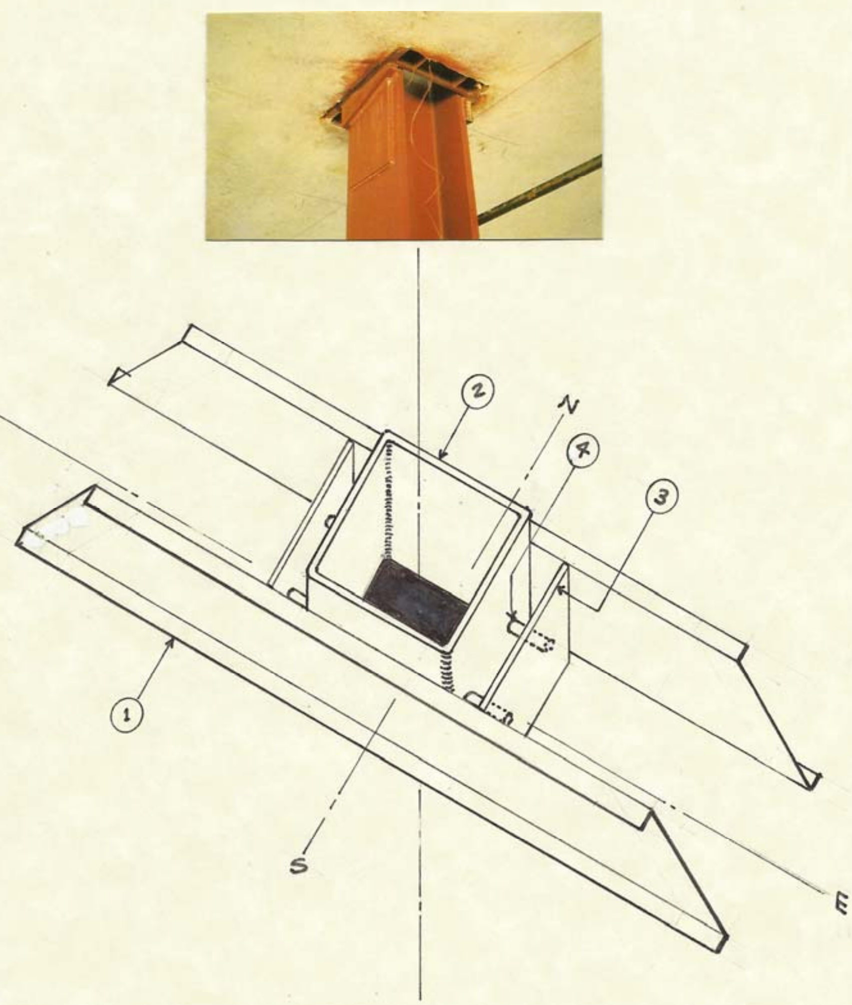
1- Strongbacks. Use a pair of 4 or 5 in. (four feet long) steel channels depending on slab thickness. Place shearhead in such a way that the legs are oriented in the direction of the slab longer span (which has arbitrarily been designated on Figure 6.1 as E-W). If the shear stresses are found to be too large to handle safely, add an additional leg in the N-S direction.

2- Lifting Collar. It is basically a piece of steel tubing properly sized to be able to slide over the column. Provide a tolerance of ¼ to ½ in. all around the collar. Long steel columns, while being detached, will allow for some degree of movement, however, there may be a need to add some grease to bypass the rough spots.

3- Bumper Plates. Both the lifting collar and bumper plates should be sized for the lifting load, but the minimum material thickness should not be any smaller than 3/8 in. These plates are also intended to contain the concrete while being poured and as a spacer for concrete coverage, therefore, it should be resting on the concrete surface below.

4- Lifting Studs. Minimum diameter should be ¾ in. and the length between 2 and 2-½ in. depending on the lifting hooks to be used. Both ends must be fully welded, one end to the lifting collar and the other end to the bumper plate.

Although a set of "hard slabs" could well be lifted, however, slab post-tensioning is highly recommended as it provides the necessary slab flexibility for a successful lift; in addition, it is an added assurance that the slabs will be crack free for the life of the building.



SHEARHEAD DETAIL
FIGURE 6.1

Note: The shearhead shown above is to be used at interior column locations only. At exterior columns the configuration need to be a shortened and unsymmetrical version.

After the slab on the top has been allowed to cure for five days, the post-tensioning is done at ground level and in a single and continuous operation. Then the slabs get lifted sliding along the previously installed full height steel columns. Lifting rates have normally been accomplished at a rate of about one inch per minute, or to put it in a more palpable way, five feet per hour.

The Lift-Slab Method can be used in any multistory building with typical floor plans. Although it can be used in buildings of any height, however, experience has demonstrated that the system is most economical for heights from 6 to 8 floors. No cranes, shores or scaffolds are needed for the erection of the slabs. The enclosed Figure 6.2 depicts a lifting job on its way to completion. The reader will notice that the slabs were lifted in groups of three and four. It would have been quite a challenge to lift the roof slab all the way to the top and having to design the supports as long columns with an overall height of fifty feet just to use on temporary basis. Therefore, it made sense to lift the slabs in groups and install them in such a sequence that as the bottom slab in the group reached its final destination it got welded in place before the lifting would proceed upwards.

Floor and roof slabs have an overall thickness of seven (7) to eight (8) inches, being suitable for spans from twenty four (24) to thirty (30) feet. Slab lifting is done by using a computer controlled synchronized system. During the decades of the 1970's and 80's it was used a complicated and messy set of stainless steel ribbons feeding from each lifting point to a tape reader which in turn fed that information to the mainframe computer which maintained the lifting with a maximum difference among columns within one-eighth of an inch of accuracy with respect to true level. However, in modern times with the advances attained in the fields of optics and laser technology, that part of the operation has been enormously simplified.

Exterior walls may be built out of steel studs, wood studs, masonry or precast panels, whichever would be the choice of the design architect. Since the roof slab is also post-tensioned, the possibility of cracking is remote. However, despite the fact that some precasters claim that the roof slab could be left bare and without the traditional roofing. To be safe we recommend a roller or spray applied liquid elastomeric membrane.

When it comes to the design of the structure, the slabs are designed based on the known principle of column and middle strips. One thing is important for the designer to consider, the slab to column joint lacks the full continuity as compared to the traditional monolithic concrete slab to concrete column conventional method. Such connection should be considered as hinged rather than fixed, therefore, the resulting structure would not be efficient in resisting lateral loads generated by hurricane winds. Consequently, the use of shear walls (or rather "X" bracings) should be taken as mandatory for buildings higher than two stories. Since all slab to column joints are taken as hinged, it would be a fair and valid assumption to say that 100% of the lateral loads should be resisted by the shear walls. On our course titled "Simplified Principles of Wind Design" we presented an example of hand computations for a five story office building with post-tensioned slabs which could have been the perfect case for an application of the Lift-Slab Method.

FIGURE 6.2

Since slab chiseling, cutting or drilling will not be allowed during construction or during the life of the building for that matter, all slab inserts and penetrations must be anticipated and provided for prior to concrete casting.

In summarizing, the most important advantages for using the Lift-Slab Method are:

- All structural work is comfortably done at ground level.
- Practically no formwork is necessary other than the perimeter forms.
- No shoring or re-shoring is necessary.
- No scaffoldings are needed for any purpose.
- No cumbersome cranes are needed in the process.
- The system saves time, money and effort for the benefit of the owner and the builder, therefore every one emerges a winner.

7.0 CLOSING STATEMENT

This course covers five selected topics which could be of the interest of those engineers and builders engaged in the construction industry. First, how to remediate that apparently spontaneous tendency of concrete to crack. Second, how to reduce concrete weight in those cases where is important and needed. Thirdly, how to raise the roof in obsolete buildings. And fifth, how to cast all floors and roof slabs at ground level and lift them to their final places.

As we went through all the above covered material, it came to mind the fact that most builders get to achieve their position through the ranks and learn their occupation by following a hands-on field apprenticeship devoted to develop a full understanding of the conventional construction methods. Much the same could be said about many engineers whose training and knowledge has been derived from professors and books written under the wrath of the same conservative and conventional wisdom. Although there is nothing wrong with all of that, however, we must realize that there is a world of unconventional thinking out there that needs to be unveiled for the sake of creativity.

This course and all those which may follow after it, deal with those unconventional ideas and methodologies which are the result of clever minds at work while trying to solve special problems encountered on the way of their pursuits. Paradoxically, in more cases than not, they did not derive any fair financial benefits for themselves, but nevertheless left behind a wealth of ideas for the rest of us to follow and explore. Some of those ideas you have already herein read about, and some other ones you will read on the following courses to come in the near future.

In Memoriam: Architect Peter Martin Vanderklauuw, AIA (1930-1999).

END