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Autor: Yee, Alfred A.

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DISCUSSION PRÉPARÉE / VORBEREITETE DISKUSSION / PREPARED DISCUSSION

Special Problems of Tall Buildings (Shear Walls, Stability of Columns, Effect of Thermal Gradients, Construction Problems)

Problèmes spéciaux aux bâtiments de grande hauteur (murs de contreventement, stabilité élastique des poteaux, effets de gradients thermiques, problèmes constructifs)

Spezielle Probleme bei Hochhäusern (Schubwände, Stabilität der Stützen, thermische Einflüsse, konstruktive Probleme)

ALFRED A. YEE
Alfred A. Yee & Associates, Inc.
1441 Kapiolani Boulevard
Honolulu, Hawaii 96814

The authors' subject is one of great interest in view of the increasing world population. In this area of design there is a need for more information to define physiological and psychological response limits. Although some information is available on tolerable structural movements based on frequency of vibration and displacement, these should be extended in scope to cover a wider range of frequencies and displacements. There should be further development of response criteria based in terms of acceleration with regard to discomfort for the human body is most sensitive to this aspect of motion. It is recognized that criteria for comfort can be difficult to establish since personal reactions to vibration vary among individuals.

There is a need for more sophisticated wind measuring devices to obtain wind gust readings within fractions of a second. This information can be valuable in determining dynamic responses of structures. Further statistic and probabilistic studies should be undertaken in order to develop a more rational design criteria for earthquake and wind loads.

The importance of energy absorption and ductility in multistory frames is well recognized by all engineers. This, however, may not be easily achieved in reinforced concrete or prestressed concrete building frames unless more emphasis is given to the detailing of primary joints between columns, beams, girders and shear elements. This is now especially important in view of the potential increase in the use of precast units for the construction of high rise buildings. It may be more advantageous to precast such primary joints between columns, beams and girders and locate the splicing points between these precast units in an area midway between the primary joints in order to optimize the quality of construction and ultimate behavior of the critical column-beam-girder intersections. For instance, Figure 1 shows a method of high rise building construction utilizing precast column-beam elements in combination with pretensioned precast concrete floor slabs. The interaction of the columns and beams at the factory-produced joints will furnish the necessary energy absorption and ductility required in the resistance of lateral dynamic forces. The bending moments due to lateral forces are usually minimal at the splice points shown and these locations will be required primarily to transmit shear under the action of lateral forces. These connections, therefore, can be simply fabricated by means of grouted sleeves joining the column reinforcing bars and cast in situ splices for the beams. This prefabrication concept provides considerable economic benefit through the advantage gained by factory work replacing a large part of in situ work in the multistory structure.

Minimum depth in structural framing systems is important for multistory buildings not only from the point of view of cost savings but also with regard to the increasingly strict height limitations now being introduced in recent zoning and building set-back regulations. Figure 2 shows the cross section of a 33-story apartment building recently constructed under strictly regulated height limitations. The basic structural concept utilizes a 3-1/2 inch thick precast prestressed concrete slab soffit in composite action with a 2-1/2 inch thick cast in situ reinforced concrete topping making a total overall depth of 6 inches in a clear span of 26 feet. The maximum overall slab span from center line of beam to center line of wall support is 30 feet 7 inches. This thin slab was built to achieve these spans through the combined use of prestressing steel and lightweight aggregate concrete. It was found that when local pumice lightweight aggregate was prestressed its stiffness increased to the extent that it developed only two thirds the deflection for dead and live load of that experienced by similar construction using regular weight blue basalt aggregate concrete. This appeared to be an unusual phenomenon inasmuch as standard reinforced concrete using this same lightweight aggregate would develop about double the deflection experienced by similar construction with regular weight aggregate. The minimum thickness of these slabs enabled the builder to construct an extra story height within the restricted building height envelop as regulated by local building ordinances.

Weight is a critical factor in the construction of multistory buildings. If lightweight aggregate concrete is used in place of standard weight concrete, the reduction in total dead weight of the building means a reduction in earthquake response forces, reduction in the reinforcing required for each basic element such as floor slabs, beams, walls, columns and finally a reduction in the size of the footings and the requirements for foundation piling. However, the apparent initial disadvantage in the use of lightweight concrete because of its normally increased unit cost per cubic yard of material has discouraged many designers from investigating it further. In the building project shown in Figure 2, a structural cost comparison was made on alternate designs using various lightweight aggregate concrete combinations versus all standard weight concrete construction and it was proven that although there was a premium of $5.00 per cubic yard on the lightweight aggregate concrete, the use of this material throughout the entire building would result in a savings of $113,100. Figure 3 is a summary of this comparative cost analysis.

Other factors that can influence multistory construction cost are methods of framing with relation to the utilities that must be accommodated. One of the framing methods that has often been successfully employed in the past few years is the interrupted beam system whereby alternate spans of the beams are cantilevered off the columns and stopped short of the midspan, thus allowing a break for the passage of air conditioning ducts. This is an effective way to reduce the floor to floor height in multistory buildings and such reduction of height means a reduction in each run of stairs, elevator shafts, plumbing stacks, vertical duct work, area of exterior perimeter walls, overturning moment, etc.

The most desirable multistory building design solution requires a complete integration of numerous factors balancing structural methods and speed of construction with accommodation of electrical, mechanical and other utilities to produce the most functional, economical and aesthetic end product. The writer agrees with the authors that, "Structural design is still almost as much of an art as a science ...".

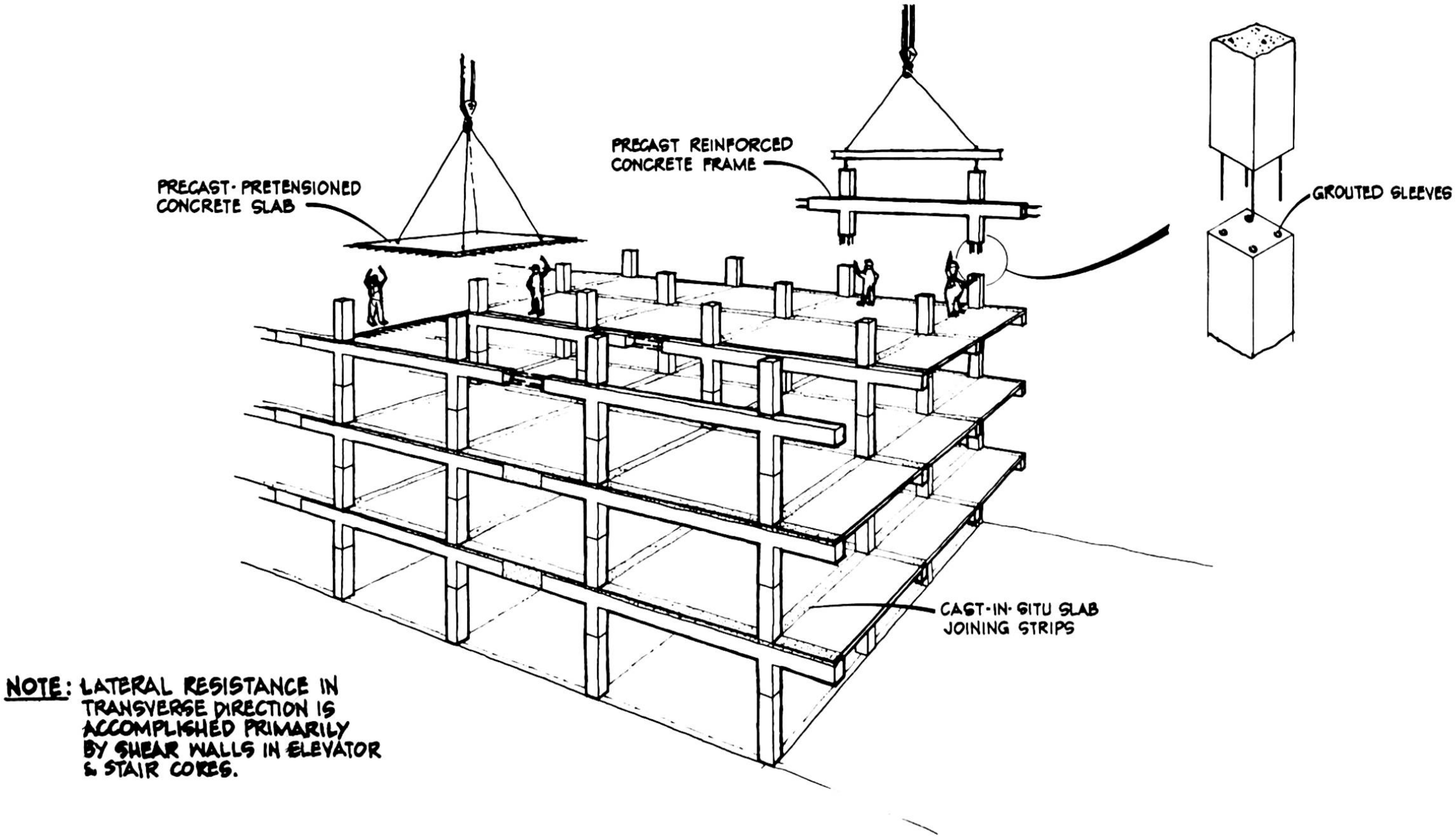
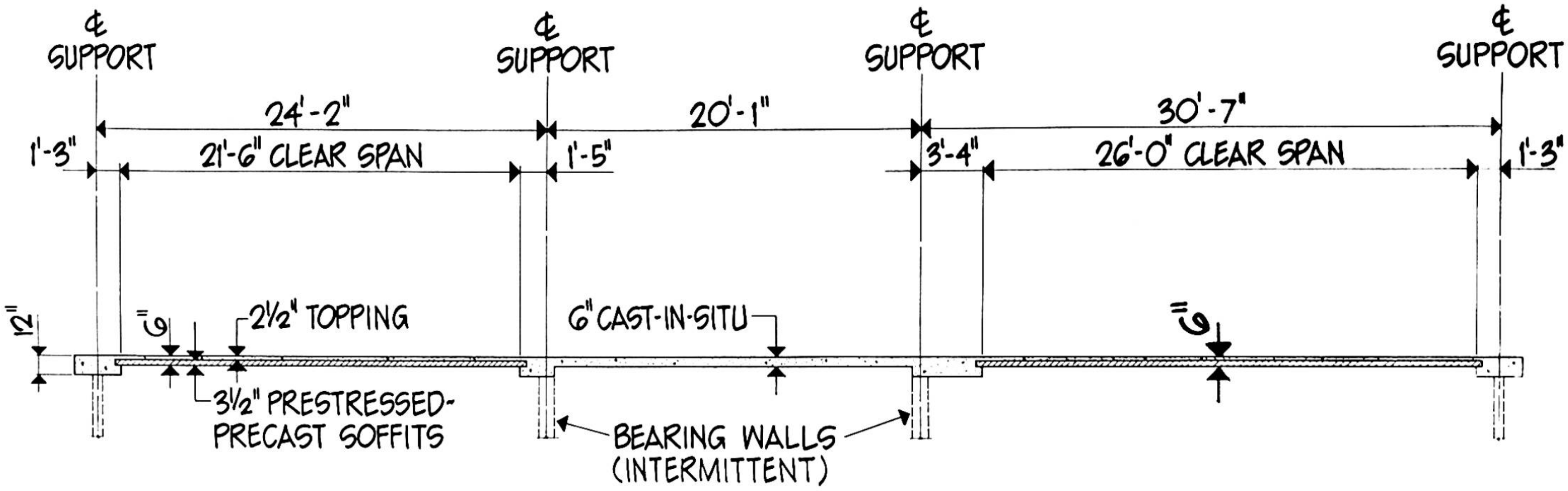

PRECAST REINFORCED
CONCRETE FRAME
PRECAST· PRETENSIONED
CONCRETE SLAB
GROUTED SLEEVES
CAST-IN-SITU SLAB
JOINING STRIPS
NOTE: LATERAL RESISTANCE IN
TRANSVERSE DIRECTION IS
ACCOMPLISHED PRIMARILY
BY SHEAR WALLS IN ELEVATOR
& STAIR CORES.

FIGURE 1



TYPICAL APARTMENT FLOOR CROSS SECTION

FIGURE 2

COMPARATIVE COST ESTIMATE WITH VARIOUS COMBINATIONS OF AGGREGATE TYPES BASED ON TYPICAL BAY EXTRAPOLATION

Schemes	Reinforcing Costs	Concrete Costs	Pile Costs	Pile Cap Deductions	Totals
SCHEME I Blue Basalt Concrete throughout	$481,700	$264,400	$590,000	$ -	$1,336,100
SCHEME II Lightweight Concrete Topping and Beams - Blue Basalt Concrete Planks, Walls and Columns	434,100	296,400	574,000	800	1,303,700
SCHEME III Lightweight Concrete Topping, Beams and Planks - Blue Basalt Concrete Walls and Columns	387,200	299,400	552,000	1,900	1,236,700
SCHEME IV Lightweight Concrete throughout	380,300	315,700	530,000	3,000	1,223,000

TOTAL DIFFERENCE - SCHEME IV TO SCHEME I $113,100

Based on the Following Unit Costs:

Lightweight concrete @ $25.00/cu. yd.*
Regular weight concrete @ $20.00/cu. yd.*

A-15 reinforcing steel @ $.16/lb.**
A-432 reinforcing steel @ $.17/lb.**

200T piles @ $10.00/ft. (prestressed concrete)

* Material only
** In-place cost

FIGURE 3

SUMMARY

The importance of energy absorption and ductility in multistory building frames is well recognized by all engineers and the most important area of consideration is the detailing of primary joints between columns, beams, girders and shear wall elements. For factory fabrication there appears to be some advantage in precasting joints between primary members and locating splicing points at positions of minimum moments under lateral forces. In view of increasing building height restrictions, some advantages can be gained in minimizing the depth of structural framing systems. The use of lightweight concrete for weight reduction in multistory buildings is especially desirable in seismic areas.

RÉSUMÉ

L'importance de l'absorption de l'énergie et de la ténacité dans les portiques à étages multiples est bien connue par tous les ingénieurs. L'intérêt primordial est porté vers les joints principaux entre colonnes, poutres, traverses et éléments de mur de cisaillement. Pour la fabrication industrielle, il apparaît avantageux de préfabriquer les joints entre éléments primaires, et de placer des raccords aux endroits de moment minimum sous charge latérale. Vu les restrictions de plus en plus sévères de la hauteur des bâtiments, il peut être avantageux de minimizer la hauteur du système de portiques. L'emploi de béton léger réduisant le poids dans les structures élevées est particulièrement recommandé dans les zones sismiques.

ZUSAMMENFASSUNG

Frühzeitig ist die Wichtigkeit der Energieabsonderung sowie die Biegbarkeit in Stockwerkrahmen von allen Ingenieuren erkannt worden; der wichtigste Teil der Betrachtung ist der der Hauptknoten zwischen Stützen, Unterzug (Träger), Hauptträger und Scheiben. Für die Herstellung scheint es vorteilhaft, die Verbindungen zwischen Hauptelementen vorzufertigen und Montagestösse dort anzubringen, wo das Moment infolge seitlicher Kräfte minimal bleibt. Aus der Sicht der wachsenden Beschränkung von Gebäudehöhe können einige Vorteile durch die Minimalisierung der Rahmentiefe gewonnen werden. Die Anwendung leichten Betons zur Gewichtsabminderung in vielstöckigen Gebäuden ist besonders in erdbebengefährdeten Gebieten erwünscht.