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Fully Integrated Composite Beams of High-rise Buildings

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Abstract

In recent years, increasing interest has been shown throughout Europe in developing and designing floor-to-floor height reduction system in steel frame of high-rise buildings.

This paper reviewed the latest design developments in composite beams and slab systems fully integrated. A number of composite slab systems developed specifically for integration in high-rise buildings were presented, namely, fabricated systems with slim floor system, flex frame, SC frame and RSC frame, iTECH beam, and TSC beam. A brief introduction of these systems is given, followed by an overview of recent research work on systems. Furthermore, the design and construction of progressive slim floor systems that can be suitable for the effective construction and can do the greatest efficiency of floor-to-floor height reduction were also discussed.

Keywords: composite beam, slab system, slim floor system

1. Introduction

The gravitation phenomenon of the population toward the city seeks efficient land utilization necessarily by fast economic growth and industrialization of today. Therefore, the effort of floor-to-floor height reduction in order to invent maximum area in limited space of high-rise building is becoming important design factor as involved with economical efficiency of high-rise building in all structural system of reinforced concrete and steel.

In the case of reinforced concrete structure, the frequency of Wide Beam System's use has been increased that can reduce floor-to-floor height to 350 mm and can elevate utility of space.

In the case of steel structure or steel reinforced concrete structure, composite slab is used mainly, but the floor-to-floor height tends to increase for slab located over the upper flange of steel beam.

At this point, many engineers tend to think that composite construction (composite beam and floor system fully integrated) is a product of recent design and construction practice, it actually began just prior to the start of the twentieth century. While many countries have their own stories to tell about composite beams and slab systems fully integrated with high-rise building. This composite construction in high-rise buildings has been well established in many countries.

The structural system of a composite beam is essentially a T-beam with a long thin concrete flange connected with a steel section. The forces between the two materials are transferred by shear connectors, usually headed studs or other connectors which are welded or shot-fired to the steel section and embedded in the concrete slab. The benefits of composite action are increased in the strength and stiffness with 1.5-2.5 times than the moment resistance and stiffness of the steel section, leading to economy in the size of the steel beam used.

The moment resistance of a composite beam is determined by the plastic analysis principle.

The objective of study is to devise structural design of the slim floor system and investigate the structural performances of new fully integrated beam-slab system in order to reduce the floor-to-floor height in high-rise buildings.

2. Composite Beams and Slab System

Generally there is always a need to incorporate a high degree of the building services within the floor zones, while the same time minimizing the depth of floor zones in order to reduce the overall height of a building. The economics of modern buildings are such that a small increase in the cost of steel frames required to integrate structural members and building services has a proportionately much smaller effect on the overall cost of the buildings. Various design solutions are feasible.

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2.1 Slim Floor System

Slim Floor Systems were developed in the 1990s in UK. The concrete slabs are placed with in the depth of primary steel beam to provide floor systems with a minimum constructional depth, as shown in Fig. 1.

That is, Slim Floor System consists of the supporting steel beam being almost totally contained within the floor system.

Universal beam sections with welded bottom plates were first introduced, and later, asymmetric steel sections with unequal flanges were specifically developed for this form of construction. The floor slab - which is usually a hollow-core slab, or in-situ concrete on concrete plank or deep profiled steel decking - is supported on the bottom flange of the beam. The floor has minimum construction depth and provides maximum freedom for distribution of service ducts between the ceiling and the flat floor. Typical beam span ranges from 5 to 7.5m, with an overall floor depth of 320mm.

Because the slim floor beam is surrounded by concrete on the sides, it possesses inherent the fire resistance, which is considerably higher than for conventional beams attached below the floor. Generally 30 to 60 minutes fire resistance is achieved without further protection. For a fire resistance period of 90 min, only nominal fire protection is needed at the exposed bottom flanges of the steel beams.

Although the slim floor systems may not be as structurally efficient as other conventional floor systems, owing to small structural depths, the overall construction cost is considered to be competitive as no or little fire protection is needed.

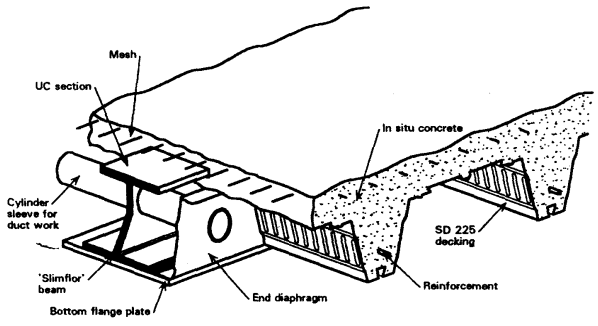


Fig. 1. Basic Components of Slim Floor System

2.2 Flex Frame

Flex frame has aimed to high-rise residential building. It is an assembly of precast concrete hollow-core slabs supported by structural steel. The steel-precast hybrid is the first to use long-span precast hollow-core slabs with an integral steel beam to form a monolithic structural slab assembly. The light-weight assembly develops composite action enabling it to support residential loads within permissible deflection range.

An invented “T” shaped beam (fabricated from a wide-flange section) used as an interior girder supported the slab on its bottom flange. The beam, concealed within the plane of slab with only its thin bottom flange exposed produces a flat plate concrete. Elimination of conventional steel beams beneath the slab, which provide support from the top flange, permits minimum floor-to-floor heights.

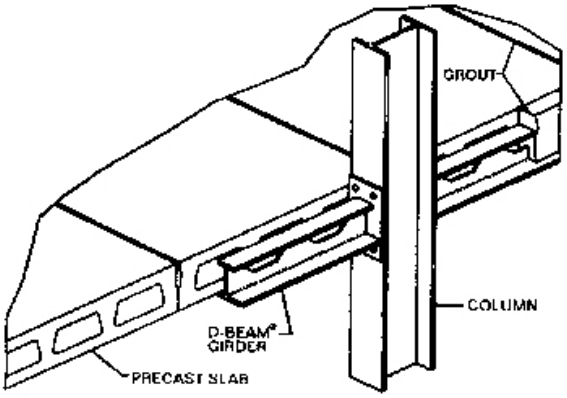


Fig. 2. Basic Components of Flex Frame

2.3 SC Frame and RSC Frame

SC Frame is a frame system developed in Europe on early by purpose to offer effective fire resistance to structural steel, witch is the composite structure that consists by SC members (SC Column, SC Beam).

SC frame is the system that first welds Tie Bar acting as stirrup between flange of H-section steel to equal space, second establishes concrete form between flanges, and finally is integrated each other to lay concrete to space between steel frame and concrete form.

RCS Frame forms the efficient joint structure system that accomplishes composition with concrete column steel beam in form of general composite structure of beam-penetration shape. RCS Frame has same advantages that reduce the constructional time as steel system's property in the constructional aspect and keep the axial force resistance ability and the strength of joint under earthquake load as concrete column's property in the structural behavior aspect.

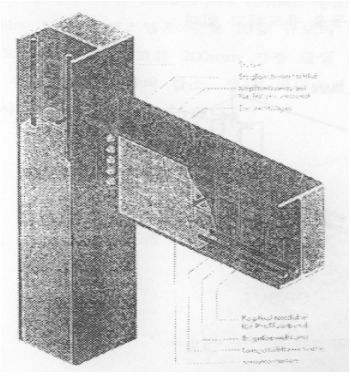


Fig. 3. Basic Components of SC frame

2.4 iTECH beam

iTECH beam is a new composite beam that improve TEC beam and A-TEC beam developed in Korea. It keeps the effect of floor-to-floor height reduction and can have the moment connections.

Existent TEC beam is composed that shear stud arranged to web both of CT steels delivers lateral shear force to compose steel frame and concrete and PC part acts like slab of fire performance improvement of steel frame. A-TEC beam that establishes plate instead of shear stud to web of CT section was developed because of the use of reshoring method when apply the TEC beam in practice. However, it was required more elevation of construction and improvement of design detail for practical use. Therefore, iTECH beam was developed, that changed PC by in cast concrete and established web opening so that it intensifies integration with concrete. iTECH can improve variability of steel frame depth and can reduce amount of materials because of production of the general H-section steel by honey comb beam cutting method.

Using web opening, the practical use is possible by duct space for service equipments.

It can also secure economic performance, and can omit stirrup required for the old and the new concrete unification according the PC change when in-situ.

2.5 TSC beam

TSC is a composite structure that is doing research and development in current Sen Structure Research Institute and applying in practice. TSC structure was stemmed from steel-concrete structure that first arranges angle or channel in outer wall corner of column or beam, assemble reinforcing rod lattice in the interval, establish the lastingness of concrete form that combines fire protection on outer side, and put the pouring concrete. But, there is no lastingness concrete form material recognized by fireproof material yet in Korea that applies this system in practice.

2.6 Comparison with Composite Beams

Table 1 shows the comparison with the type of composite beam and slab systems.

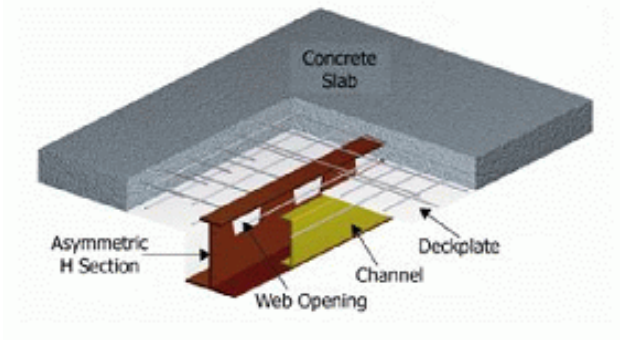


Fig. 4. Basic Components of iTECH Beam

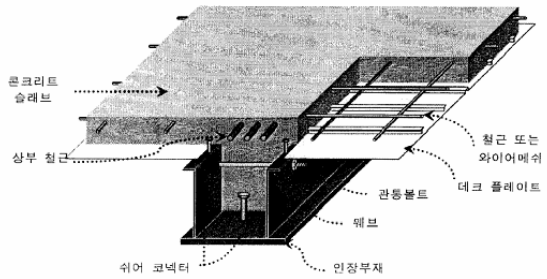


Fig. 5. Basic Components of TSC Beam

Table 1. Comparison to the systems

	Slim Floor System	Flex Frame	SC Frame	iTECH beam	TSC beam
advantage	Floor beam integrated into slab Inherent fire resistance No formwork required	Low cost Fast erection Materials prefabricated under controlled conditions	composite action of concrete and steel frame retrenchment of form work	steel frame amount of materials decrease. Improve of horizontality shear strength and integration by putting web opening with the concrete	Prevention of crack and neutrality Extend durability Excellent use of deflection, vibration
Dis-advantage	Fire proof only with additional protection or reinforcement Transverse service installations problematic Difficult for unconventionally shaped ground floors	Application to the field is in difficulty	Problems of manufacture in factory and conveyance, keeping in field	Verification necessity for use	Nonexistence of permanent form recognized by fireproof material in Korea

3. Alternatives of Slim Floor System for High-rise Building

From the results of investigation about floor-to-floor height reduction system, the application of that system has some difficulty in planning process.

In the case of slim floor system, research for application has been done by the method of Semi-Slim Floor Beam, or Slim Floor System using deep composite steel decking.

In the case of semi-slim floor beam that steel frame beam section includes the part of slab by locating general composite steel deck plate to steel frame beam's web, the following problem happens; 1) composite effect is less than fully slim floor system because of filling up the concrete to upper part of only steel frame beam; 2) extra angle should be welded for slab support; 3) fire-protection of the steel members is needed.

If it is developed that the design and the connection details can supplement these problem, it can improve the economical efficiency and constructability through Slim Floor System's activation.

Therefore, this research has been done for the slab system suitable for the high-rise building and for the greatest efficiency of floor-to-floor height reduction.

Structural plan of the proposed building is in Fig.6, and span length of the objective beam is 9.0 m.

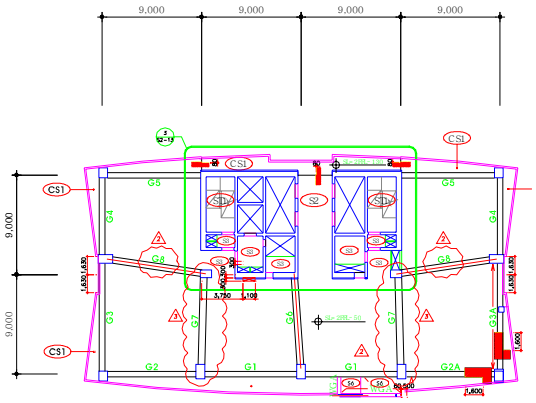
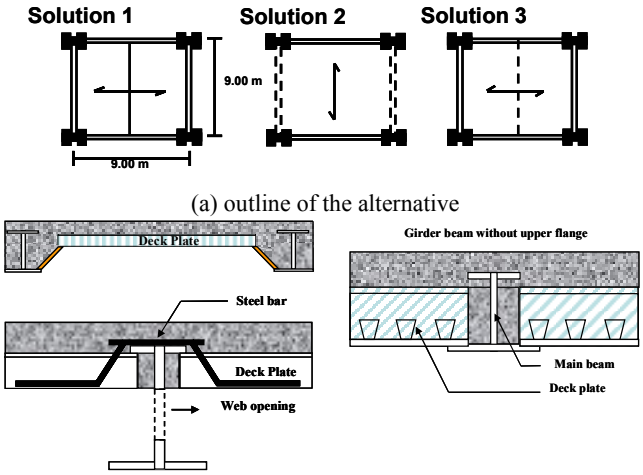


Fig. 6. The Plan of applied building

Therefore, as shown in fig.7, three solution methods were proposed. Solution 1 is the general steel composite beam that secondary beams are needed. Solution 2 is devised to prove more performance to be possible to long span based on slim floor system. The system is for solving the problem of main beam application and increasing the strength by in-suit concrete. Sloution3 is that the secondary beam was applied and planed by slim floor system.

4. Conclusions

Composite beam based on slim floor are now recognized as one of the most effective form of steel frame slab system. This type of composite structural system will undoubtedly play a major role in steel structure design in the coming years because of the their economy and structural efficiency. Solution 2 of the proposed alternatives can get floor-to-floor height reduction effect of 90 mm suing slim floor system. The following research includes the analysis and experimental work including fire test for those selected alternatives.



(a) outline of the alternative

(b) Section of solution 2 (c) Section of solution 3

Fig. 7. Proposed Integrated Composite Beam and Slab

Acknowledgements

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References

Bailey, C. G. and G. M. Newman (1998) The design of steel framed buildings without applied fire protection. Structural Engineer

Chung, K.F. (2002) Composite beams and floor systems fully integrated with building services. Prog. Struct Engng Mater

Mullett, D. L. (1998) Composite Floor System. The Steel Construction Institute

Mullett, D. L. (1992) Slim Floor Design and Construction. The Steel Construction Institute

Naccarato, P. A. (2001) Steel and precast slab construction system for mid and high-rise residential buildings. Modern steel construction

The European Convention for Constructional Steelwork (1995) Multi-storey buildings Design Guide for Slim Floor with Built-in Beams