Advanced Technology for Speedy Construction (Tunnel Formwork)

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Abstract: In this project we plan to explain about the construction method using tunnel form technology and design and analyze an S+4 building using ETABS software. The tunnel form technology is one of the advanced methods of construction. Using the tunnel formwork technology the time of construction of a building can be greatly reduced. Due to usage of tunnel form construction we eliminate plastering. The design for the tunnel form construction is quite difficult, but the tunnel form structure can withstand large amount of seismic force. This project we mainly concentrated on analyses the seismic behavior between shear wall structure and the framed structure, and the construction procedure like assembling and handling of the tunnel formwork. These buildings can adopt in the earthquake prone areas and also adopted for the cellular and similar structure.

Index Terms- Tunnel Formwork, Plastering, Cellular, Earthquake, Shear wall.

INTRODUCTION:

A recent trend in the building industry in India, as well as in many countries with increasing city populations, is toward utilizing the tunnel-form (shear wall) construction system for development of multistory residential units. This has been driven basically by the need to construct earthquake resistant multistory reinforced concrete (RC) buildings with considerable ease, speed and economy. The tunnel-form system is an industrialized construction technique in which structural walls and slabs are cast (in situ) simultaneously using steel forms composed of vertical and horizontal panels set at right angles. To expedite the construction, non-structural components such as facade walls, stairs and chimneys are commonly produced as prefabricated elements. Tunnel-form buildings generally have a symmetrical configuration in horizontal and vertical planes that enables continuous flow of construction and better quality assurance. Besides the constructive advantages, tunnel-form buildings provide superior seismic performance compared to conventional RC frame and dual systems, which suffered significant damage and total collapse in many regions during recent devastating earthquakes in India.

Continuity of shear-walls throughout the height is recommended to avoid local stress concentrations and to minimize torsion. Such a strict shear-wall configuration in the plan and throughout the height of the building may limit the interior space use from an architectural point of view, and this is one of the disadvantages of tunnel form buildings. During construction, walls and slabs, having almost the same thickness, are cast in a single operation. This process reduces not only the number of cold-formed joints, but also the assembly time. The simultaneous casting of walls and slabs results in monolithic structures unlike any other frame-type RC buildings. Consequently, tunnel form buildings gain enhanced seismic performance by retarding plastic hinge formations at the most critical locations, such as slab–wall connections and around wall openings.

The increase in duration of construction greatly affects the construction cost. Selection of best formwork system gives best result in cost saving. Formwork consists of 20-25% of total cost of project. So that used advanced formwork system helps in cost saving as reduction slab cycle time. This study is done for comparative analysis of tunnel formwork system used for high rise building construction.Formwork systems are key factors in determining the success of a building construction project in terms of cost, speed, quality and safety of work. Formwork constitutes 30% of the cost and 60% of the time in concrete construction. Quality of concrete finish and soundness of concrete depends very much on the formwork system. Formwork should be properly designed, fabricated, and erected to receive fresh concrete. If formwork is not done properly the desired shape of concrete is not possible.

2. OBJECTIVE AND SCOPE

The objectives of our project are

I. To analyze the seismic behavior of the tunnel formwork building.
II. To compare the tunnel formwork building and conventional building design.
III. To compare the tunnel formwork with conventional formwork.
IV. To study the methodology of the tunnel formwork.

3. THEORETICAL CONTENT

3.1 Types of formworks

At present in Indian construction industry various types of formwork systems being used. Based on type of material, purpose of use and method of erection formwork systems listed as follows.

1. Conventional formwork.
2. Climbing formwork system.
3. Slip formwork system.
4. Permanent formwork.

5. Mivan/ Aluform/ Aluminium formwork
6. Tunnel formwork.

3.2 INTRODUCTION OF TUNNEL FORM

Tunnel formwork is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day. The structure is divided into phases. Each phase consists of a section of the structure that will cast in one day. The phasing is determined by the program and the amount of floor area that can be poured in one day. The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and slabs shall be poured in one single operation. The formwork is stripped the early morning and positioned for the subsequent phase.

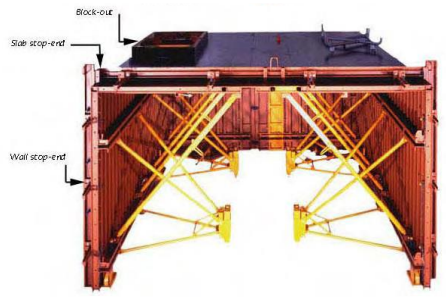

Fig no 3.2: Standard tunnel formwork

3.3 COMPONENTS OF TUNNEL FORMWORK

1. Angle Formwork: Inner and outer angle configurations are designed to attach to 1.25m wall forms to obtain a 150mm wall. Spacers shall be installed for producing wall thicknesses.
2. Back Panel: The back panel allows pouring of cross walls, other walls, walls and slab in one operation.
3. Slab Stop End and Wall stop: These can be adjusted to fit the lengths of wall and slabs. These remain fixed to the form during all handling operations.
4. Kicker Form: In order to guide the walls of the upper floor precisely above the walls of the floor below, a kicker form is fixed to the tunnel form before pouring the concrete. Slab and starting walls are then poured during the same phase.
5. Box Out: During each phase, window box out, door box out and slab box out are mounted on the tunnel using a magnetized system.

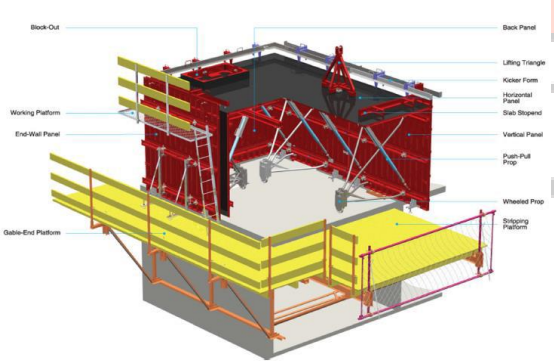

Fig no 3.3: Components of tunnel formwork

3.4 WORKING CYCLE`

1. The 24 Hour cycle defines the works to be done each day. To establish this cycle, the overall structure is divided into a number of more or less
2. Similar construction phases, corresponding to a day's work.
3. The necessary manpower and equipment are then determined according to the size of these phases.
4. To reach maximum efficiency, the phases done every day are similar.
5. The cycle is divided into the following activities:
    a. Initial striking operations
    b. Movement of forms
    c. Final preparation
    d. Pouring
6. However, early removal of formwork for wall is possible with proper design of concrete mix, accelerated warm curing and using suitable chemical admixture.
7. The implementation of 24 Hour Cycle shall be in accordance with IS 456:2000 – Code of practice for plain and reinforced concrete.

8. However, the structural engineer shall furnish details about the actual process of removal of formwork after casting of concrete.

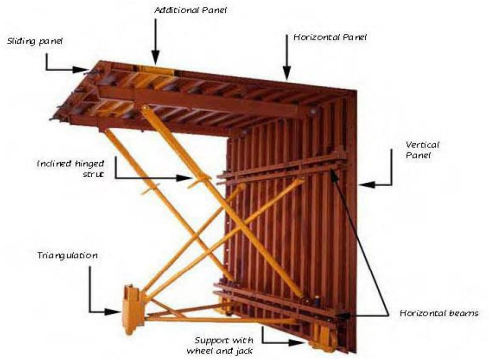

Fig no 3.4: Half tunnel form

3.5 ADVANTAGES AND DISADVANTAGES

3.5.1 Advantages

I. Time Advantages

1. A production cycle of 1-3 days can be achieved.
2. Depending on the production speed of load bearing system succeeding production activities in the building can also be accelerated.
3. The project can be completed in a short time compared to traditional construction systems.
4. Due to accelerated production, effects of climatic conditions on productivity are minimized.

II. Quality Advantages

1. Higher precision in production of walls and slab units (1/1000 deformation is allowed and can be achieved)
2. Smooth surfaces for the walls and slabs are obtained that can be covered with wallpaper right after easy and quick cleaning.
3. Standard dimensions for the other components such as carpet, windows, and doors can be applicable due to strict dimensions of load-bearing system elements.

III. Cost Advantages

1. Formwork cost per m2 (or per housing unit) can be reduced by using formwork up to number of times.
2. Due to smooth surfaces, walls and slabs do not need any additional finishing such as plaster.
3. Early completion of project provides financial opportunities such as rental incomes.
4. Repetitive nature of buildings provides effectiveness in production and minimization of labor costs.

3.5.2 Disadvantages.

1. Investment cost of formwork system increases formwork cost per m2 if project is small sized.
2. A continuous and fast cash flow that complies with the speed of production is essential.
3. Due to high production speed management-related functions are vital. Coordination problems cause remarkable delays in schedule.
4. Skilled labor force is needed compared to traditional systems.
5. Equipment costs are relatively higher due to the cranes that are needed by each block.

4. CASE STUDY

1. **Name of Contractor:** Central public work department.
2. **Name of project:** Construction of 152 Nos. type-II, 304 Nos, type-II and 76 Nos, Type- IV for central revenue quarters at ranganthan garden, Anna nagar west, Chennai, Sub work – 1: Building portion incliuding pile foundation, internal water supply, sanitary installation, drainage. Sub work-2: package C1- providing internal electrical installations and fans, package c2-providing 28 numbers 13 passengers lifts and 7 number 1500 kgs capacity goods lift, pakage – c3 providing fire fighting wet riser and sprinkler system, package- c4 providing addressable fire alarm system.
3. **Location:** INCOME TAX DEPARTMENT, Government of India, central revenue quarters at ranganthan garden, Anna nagar west, Chennai.
4. **Estimation cost:** 177,32,17,750

5. **Date of commencement:** 23-07-2016
6. **Date of completion:** 22-02-2019
7. **Scope of work considered:** Sub work – 1: Building portion incliuding pile foundation, internal water supply, sanitary installation, drainage. Sub work-2: package C1- providing internal electrical installations and fans, package c2- providing 28 numbers 13 passengers lifts and 7 number 1500 kgs capacity goods lift, pakage – c3 providing fire fighting wet riser and sprinkler system, package- c4 providing addressable fire alarm system.
8. **Type of formwork used:** 1rd to 18th floor: Tunnel formwork.
9. **Contractor hired for execution:** Mesa tunnel formwork, Turkey.
10. **Structural designing consultant:** M/s Jehovahking engineering consultants. LTd, NO 15 ground floor, garment complex, SIDCO industrial estate, guindy, Chennai 600 032.
11. **Soil investigation consultant:** M/s Geo marine consultants (P) ltd.
12. **RCC consultants:** M/s D.E.C Infrastructure & Projects (India) Pvt Ltd.

Fig no 4.1: tunnel form construction at central revenue quarters, Anna nagar west, Chennai

5. COMPARISON OF STRUCTURE

We have done the analysis between the framed structure and the shear wall structure (by tunnel formwork) in the ETABS software. We mainly compare the value of the modal mass participation ration, with that we can able to find whether the building has torsion or not. In the first two modes the torsion should not come then only it can able withstand the seismic force. While analyzing our structure, torsion is not occurring at the first two modes but on the framed structure on the second mode torsion is occurring, so that during earthquake it cannot able to with stand the seismic force. We did dynamic analysis in the ETABS.

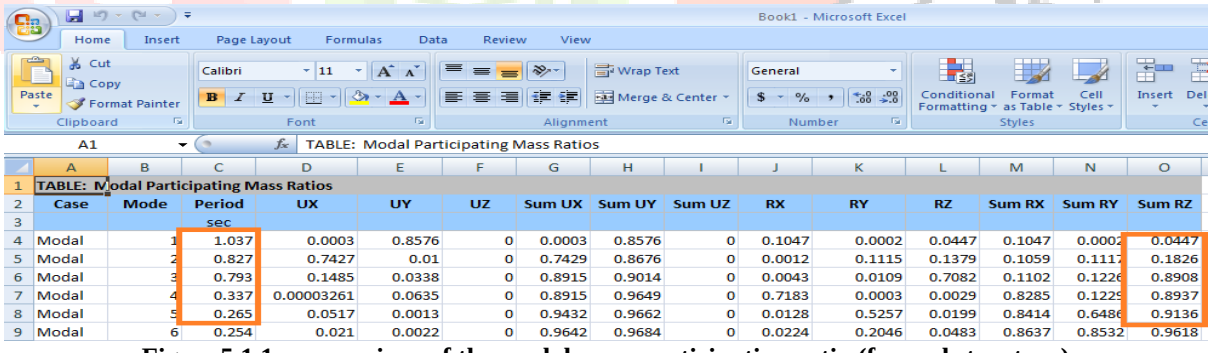

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	Sum UX	Sum UY	Sum UZ	RX	RY	RZ	Sum RX	Sum RY	Sum RZ
		sec												
Modal	1	1.037	0.0003	0.8576	0	0.0003	0.8576	0	0.1047	0.0002	0.0447	0.1047	0.0002	0.0447
Modal	2	0.827	0.7427	0.01	0	0.7429	0.8676	0	0.0012	0.1115	0.1379	0.1059	0.1117	0.1826
Modal	3	0.793	0.1485	0.0338	0	0.8915	0.9014	0	0.0043	0.0109	0.7082	0.1102	0.1226	0.8908
Modal	4	0.337	0.00003261	0.0635	0	0.8915	0.9649	0	0.7183	0.0003	0.0029	0.8285	0.1229	0.8937
Modal	5	0.265	0.0517	0.0013	0	0.9432	0.9662	0	0.0128	0.5257	0.0199	0.8414	0.6486	0.9136
Modal	6	0.254	0.021	0.0022	0	0.9642	0.9684	0	0.0224	0.2046	0.0483	0.8637	0.8532	0.9618

Fig no 5.1.1: comparison of the modal mass participation ratio (framed structure)

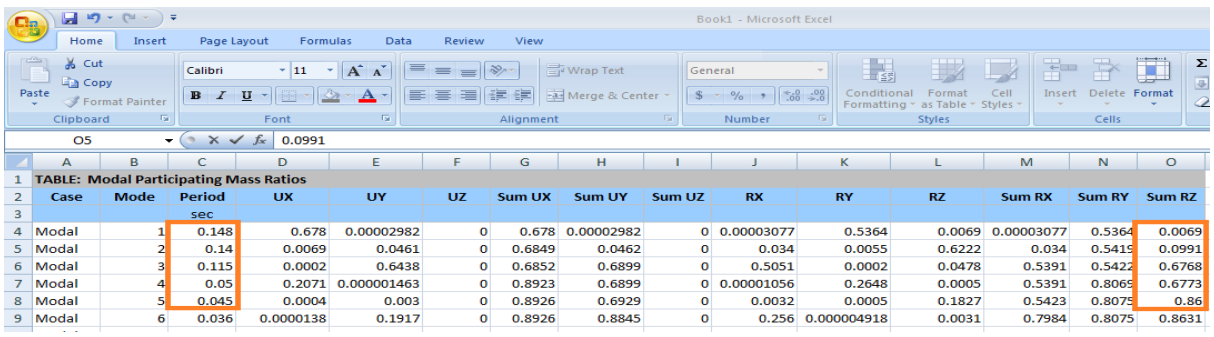

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	Sum UX	Sum UY	Sum UZ	RX	RY	RZ	Sum RX	Sum RY	Sum RZ
		sec												
Modal	1	0.148	0.678	0.00002982	0	0.678	0.00002982	0	0.00003077	0.5364	0.0069	0.00003077	0.5364	0.0069
Modal	2	0.14	0.0069	0.0461	0	0.6849	0.0462	0	0.034	0.0055	0.6222	0.034	0.5419	0.0991
Modal	3	0.115	0.0002	0.6438	0	0.6852	0.6899	0	0.5051	0.0002	0.0478	0.5391	0.5422	0.6768
Modal	4	0.05	0.2071	0.000001463	0	0.8923	0.6899	0	0.00001056	0.2648	0.0005	0.5391	0.8069	0.6773
Modal	5	0.045	0.0004	0.003	0	0.8926	0.6929	0	0.0032	0.0005	0.1827	0.5423	0.8075	0.86
Modal	6	0.036	0.0000138	0.1917	0	0.8926	0.8845	0	0.256	0.000004918	0.0031	0.7984	0.8075	0.8631

Fig no 5.1.2: comparison of the modal mass participation ratio (shear wall structure)

6. CONCLUSION

Comparing the base reaction, modal mass participation ratio, modal load participation, response spectrum between conventional and tunnel form constructed building (shear wall structure) the results are for better and safe than the conventional building. We can see that the value of summation of the reaction in the Z direction for the conventional building is higher than the shear wall building (tunnel formwork structure), higher the value of reaction in the z direction will create torsion. The torsion should not occur in the first two modes, if it occurs means the building they cannot withstand seismic force during the earthquake. So those tunnel form buildings can with stand more seismic force than the framed structure.

The designing and analysis of the tunnel formwork building is quite complicated than the conventional building, but the tunnel formwork building are seismic resistance, the construction of the tunnel formwork building will be finished within less period of time than the pre-cast building and other conventional building. Construction period is less so that the labor cost of the building will also be reduced. The building is constructed using the formwork so that plastering does not required. The plastering in the building will be reduced, so that the materials used for plastering can be saved. As we conclude that the construction of large multistory and cellular structure can be constructed efficiently using tunnel formwork than other construction technique.

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