First International Conference on Construction in the 21st Century (CITC –II)
"Sustainability and Innovation in Management and Technology"
10-12 December, 2003, Hong Kong

Studying of Elastic Plastic Behavior of Concrete Ceiling, Joints, Supports by Live Load

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Abstract

In Asemaneh building, steel structure and concrete slab has occurred misfit steel members and unknown quality of concrete slab sections. Steel long plate connections in supports were replaced by angle shapes connection in joints. New Kormit concrete ceiling was executed and there is not any theoretical criterion for concrete acceptation. Two main problems were solved by Loading Test on ceiling concrete.

- It was made a strip line of live load (wet bricks) parallel the axial of concrete slab beams.
- Live load settlement was measured by accurate instrument before and after loading.
- Computer drew deflection 3D map.

Qualification of ceiling was obtained by support condition movements and maximum settlement at mid point and zero slop in support. 3D map of live load test have concluded the right shape of angel ∟ connection. Therefore this method could be used in conditional structure, where it is needed to control quality of members and joints.

Keywords

Warping, Center of Stiffness, Live Loading, and 3D map, Ceiling Stiffness

1. Introduction

Quality control of concrete ceiling is the more controversial discussion in workshop when the concrete was executed. In addition, steel connection behavior should be tested especially in modified members and re-welded connections. ACI318 building code, live load test could be used to explaining the new method of ceiling loading. Sometimes in steel frame is needed to fit members by extra cable tension in misfit members for erecting frame. In this case, nuts and bolts steel plates should be modified by new welding connection and it is necessary to check the new replacement connection by live load test. The more advantage was produced by this method of live loading test that it could be recognized every desired point of concrete to need quality control of concrete steel frame. It is mentioned that the tension is not allowed to tense by extra cable tensional instruments. The torsion and deflection were occurred by extra cable force in frames it should be return to initial position to omit the residual stresses.

2. Warping and Modification Criterion

2.1 Steel Frame

In steel frame building Asemaneh some misfit and warping were occurred with below items:

- One miss-fit of main steel beam , Δ_X = -5 and other Δ_X = -6 cm cm
- Tensile instruments acted extra tension on frame.

Consideration above item can be resulted below:

- steel skeleton torsion and warping in steel members (columns)
- undesired bending moments in columns and beams

2.1.1 Modification method of steel frame

Modify processing is needed to add an L-shape steel connection (steel angel) where the members were cut to return in the initial shape and the residual deflection (or torsion movement) should be absorbed to erect column plump line. It is mentioned that the asymmetry torsion was created by misfit displacement in the steel structure. Modifying steps are recommended below:

- Center of gravity and stiffness should be found.
- Measuring the torsion & displacement (θz,θx,θy)
- Warping columns should be cut to separate frame into tree static stability that it is rigidity fixed at the foundation (refer to Figure 1).
- Modified members should be control again (θz, θx,θy).
- Plastic deformation of beams and columns must be recognized. Decreasing the live load.
- Un-justify displacement (θz,θx,θy) could be fixed again by opposite tension force against desired columns (by using step 1).
- Adding L-shape in cutting connection. Rigidity behavior should be guaranteed.

Above Steps could be guaranteed the final test of steel frame. Notification, in each odd span, beams constrains should be released where the span is needed to convert a tree shape(refer to Figure 1).

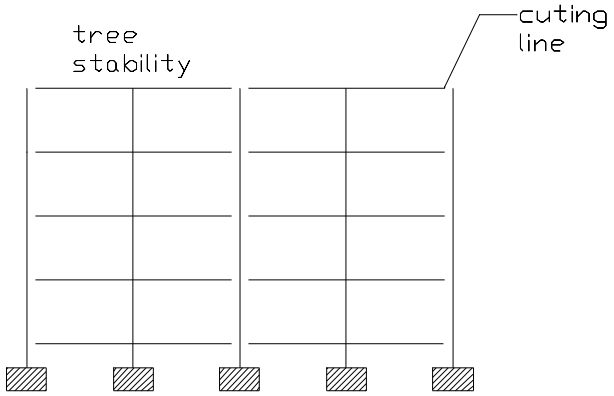

Figure 1. Tree stability by cutting connections

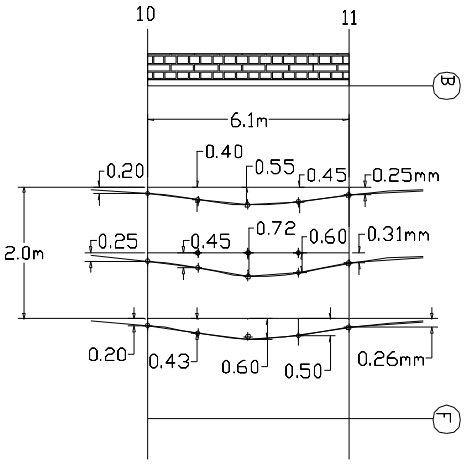

Figure 2. Deflections

2.2 Concrete ceiling

Another problem was obtained simultaneously by uncertainly concrete design that it had been made for new Kormit ceiling. Main problem could be defined with below items:

- Notebook design has not matched with steel I-beams dimensions
- Concrete mix design is differed to compare aggregate limitations (aci).
- Unknown ultimate loads, live and dead.

2.2.1 Concrete modification

Suggestion methods are set below to modify problems that it is occurred by three items above:

- Compulsory end beam rigidity; it is obtained by adding two bend hook steel bars that it is placed between main girder and end of each lateral I-beam (Figure 3).
- Cement increasing; C in C/W ratio was increased in constant ratio.
- The T-shape steel support should be placed in each end of lateral steel beams of ceiling.

2.3 Simultaneously modification

After above, a criterion behavioral is needed to control deflection and plumb-lines when the modification steps are exerted on structure to fix movement. The load test based on aci318 could be verified the operations and random load test could be used in operations.

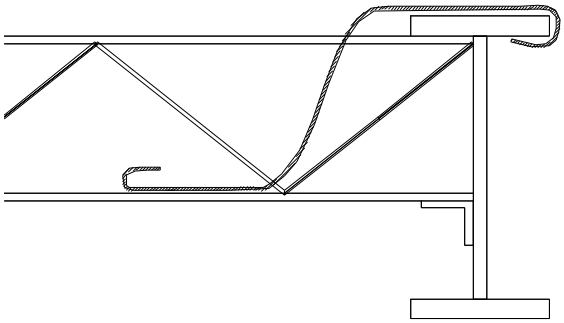

Figure 3. Hook steel bars in end. Lateral beam support is designed by rigid joint.

3. New Live Load Test and Value Measurement Method

Safe and complete test should be recognized the three steps below:

3.1 At Rest Condition

The concrete surface is clear against any live load and allowable resistance is started by during 45 days. Concrete with type 5 is used to serve at least 45 days.

3.1.1 Bench mark

A bench mark point should be determined in special part of structure that this point must be keep away from any settlement or influence radius (deflection is zero or away from test span).

3.1.2 Nailing

Steel nails (l=50mm, d=2mm) should be driven in concrete ceiling where it is needed to determine the deflection curve. Accurate surveying instruments can be used to measure deflections.

3.2 Measuring value, live load test with specific material (wet bricks)

Live load is defined to carry the wet bricks comfortably. Dry Brick will be damped to wet by water.

3.2.1 Load condition and boundary

Live load boundary is limited by supervisor engineer which the deflection should be measured for conclusion and interpretations. It is mentioned that square nailing areas ($14\times14cm^2$) have been getting used in blanked space surveying measurements.

3.2.2 Studying of parameters

Importance notice, the main opinion could be clarified parameters to choose the load span that it is contained a two meters width stripe live load and it should be parallel the beam axes. Wet bricks are used to complete loading and all dry bricks should be set in desired boundary to starting measurements. It may be contained the below items:

- The steel members misfit
- Concrete ceiling bending stiffness
- Maximum concrete settlements
- verifying steel connection in critical frames
- torsion behavior of side span
- needs to control the allowable movements

3.3 Measuring value, Un-loading condition

During 24 hours, if the q_{ult} has been chosen less than elastic load, residual deflection is return again (elastic behavior). The maximum load could be acted on concrete members less than %75 of total ultimate load (aci318). In this case, the load is exerted up on the members by plastic condition and the residual deflection is remained in near the initial point. Notification, the concrete ceiling is named one-side by one side resistance in lateral ceiling beam. Therefore the loading should be made on strip.

4. Interpretation of 2&3 Dimension Deflection Map (2DDM & 3DDM)

2DDM is set by a group of curves which they shall be explained with below steps:

4.1 Longitudinal Sections

It can be shown the deflection points that they have been settled under live load lines with support specific conditions. The maximum deflection is appeared in the mid point of span in rigid and symmetrical supports. Also, another advantage will be obtained to determine bellow items:

- Slop determining in each end, zero in fixed supports. Non-zero slop could be interpreted.
- Deflection curve
- beam symmetrically considerations
- bending moments in each ends
- Earthquake engineering parameters, stiffness matrix K, it is obtained by $P=K.\Delta$ (Equation 1).
- Rigidity percentage (steel frames end).
- Verifying of steel connections, actual and theoretical resistance comparison.

Notification, last three items had discussed to clear replacement connection that it was installed by supervisor engineer and designed clam. Designer (Tazand, consulting engineering co. ltd.) has been

$$M_A = \frac{2EI}{L}(2\theta_A + \theta_B - \frac{3\Delta}{L}) - M_{fixed}, \qquad M_A = M_{fixed} \Rightarrow \frac{EI}{L} = \frac{M_{fixed}}{(2\theta_A + \theta_B - \frac{3\Delta}{L})} \tag{1}$$

believed to prove the not sufficient rigidity of L-connection that it was placed by supervisor engineer in the workshop . The Figure 2 could be defined the correct behavior (symmetrical conditions).

4.2 Widthwise sections

In theoretical concepts, the one-side beam could be elected the total bending moment in lateral axes; therefore using lateral curve in limited to produce bellow items:

- Side-way deflection curve (Figure 2 , 5)
- Lateral behavior

4.3 Plan or contour map

These kinds of maps are used to interpret the resistance of steel members in pointed joints and it could be determined to approve safety of test load. Some advantages have been resulted during the test:

- Vectors displacement
- Scalar displacement
- Distribution displacement

4.4 Steel frame

It is used specially to determine connection reactions in each end of steel plate girders, in safety concepts, the final check could be assessed by compatibility curve.

4.4.1 Concrete ceiling

Main purpose was decided by uncertainly safety design. It could be tested to result the maximum deflection of the settlement curve that it should be determined to compare with allowable value.

5. Drawing Curves

By Referring to Figure 4, actual settlement and slope are shown to compute by Eqution2 and 3. Supports rigidity condition could be taken to prove modification by slope at each end of the lateral beams.

$$q = \alpha \times \beta(1.4q_{Dead} + 1.7q_{Live}) \quad ,\alpha = 0.75(ACI318)$$

$$\beta = Effective \quad Width\,of \quad Beam \quad = 0.72m \quad ,q = 0.75 \times 0.72(1.4 \times 550 + 1.7 \times 500) = 875\frac{kg}{m}$$

$$\frac{qL^2}{12} = \frac{875 \times 6.1^2}{12} = 2.713 \quad t.m \quad E \quad = 2 \times 10^5 \quad (\frac{kg}{cm^2}) \quad ,I = \quad = 10^4 \quad (cm^4)$$

$$\theta_a = 0.0013^R \quad ;\theta_b = -0.0019^R \quad ,\Delta = 3.1 - 2.5 = +0.6 \quad mm \quad ;L = 610 \quad cm$$

$$M_a = \frac{2EI}{L}\left(2\theta_a + \theta_b - 3\frac{\Delta}{L}\right) - \frac{qL^2}{12} \quad ,M_b = \frac{2EI}{L}\left(2\theta_b + \theta_a - 3\frac{\Delta}{L}\right) + \frac{qL^2}{12} \qquad (2), (3)$$

$$M_a = \frac{2\times(2\times10^5)\times(10^4)}{610}(0.0007) - 2.71 \times 10^5 = -2.66 \quad t.m \quad \leq -\frac{qL^2}{12} = -2.71t.m$$

$$M_b = \frac{2\times(2\times10^5)\times(10^4)}{610}(-0.0025) + 2.71 \times 10^5 = +2.55 \quad t.m \quad \leq \frac{qL^2}{12} = +2.71t.m$$

6. Points about Stiffness (EI/L)

By using Equation 1, it is possible to access the real value EI/L that it is related the actual stiffness of concrete members. First, the desired span should be fined to loading by symmetrical position and conditions. Therefore the M_a could be evaluated to substitute in Equation 1 by Equation 4 to 5 that it could be clear the symmetric phenomena. Coefficient D_{Turk} is defined by deflections that all deflections should be measured to substitute in Equation 4 and 5 in workshop.

$$L \to M_a = \frac{2EI}{L}(2\theta_a + \theta_b - 3\Delta_b / L) - \frac{qL^2}{12} \tag{4}$$

$$L/2 \to M_a = \frac{2EI}{L/2}(2\theta_a + \theta_c - \frac{3\Delta_c}{L/2}) - \frac{q(\frac{L}{2})^2}{12} \tag{5}$$

$$\Rightarrow Equation \quad (4),(5) \to EI = F(\theta_a, \theta_b, \theta_c, \Delta_b, \Delta_c, q, L) \to \quad EI = D_{turk} \times qL^3 \tag{6}$$

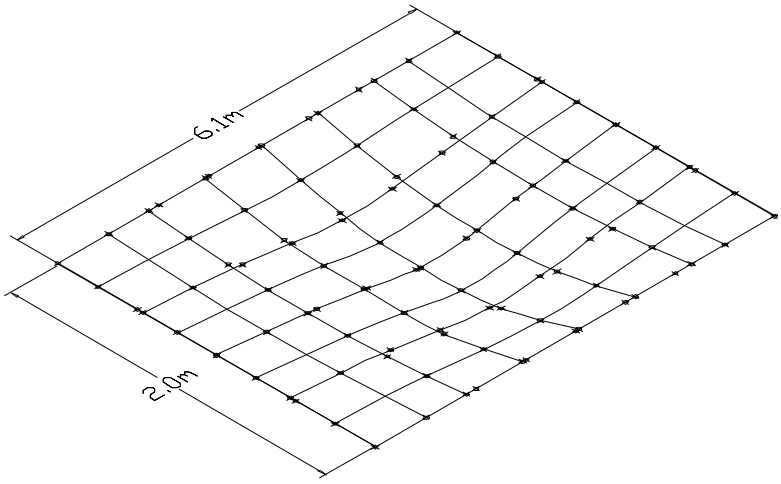

Figure 5. Space deflection is shown by contour map of curves.

7. Conclusion

The misfit steel members could be solved simultaneously with uncertain concrete design if the project is used new live load on ceiling concrete. Also, stiffness of concrete members could be completed to use in earthquake and dynamic engineering design (Equation 6). Important notice should be considered to evaluate EI/L, that it is experimental value and it could be compared with theoretical EI/L (or EI).

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