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The Design of Spring Supported Floor for Rotary Printing Presses

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ABSTRACT: Rotary printing press introduces imbalance force on the supporting floor and causes periodic vibrations that impair printing quality of the press. Appropriate application of spring isolators with damping can reduce the system response and ensure printing quality. In the fall of 1999, Moh and Associates, Inc. was chosen by a newspaper corporation to design the spring supported reinforced concrete floor of printing presses in an existing frame structure. The main objective of the design, in addition to providing static loading capacity, is to fulfill the limitation of vibration velocity of the floor required by the press manufacturer. This paper describes details of the mentioned analyses and design. In addition, results of measurements of vibration behavior during operation of press are discussed and compared with those of numerical analyses. With the construction of Taiwan High Speed Railway, the vibration caused by high-speed train at the nearby Hi-Tech plants (e.g. Fab) becomes a prominent issue in Taiwan. Research institutes and consulting firms are putting more and more effort on structural vibration problems. The experience and knowledge obtained from such projects together contribute to further development of research and design of vibration isolated structures.

KEYWORDS: Isolator, springs, press, vibration, reinforced concrete.

1. INTRODUCTION

In the fall of 1999, a newspaper corporation in Taipei planned to construct a reinforced concrete floor in an existing frame structure in order to accommodate a new set of press units. Moh and Associates, Inc. was chosen by the newspaper corporation for providing the designing service and construction management of the project. The construction of the floating floor was completed in September 2000, and press units were installed and put into operation in the spring of 2001.

The main objective of the design, in addition to providing static loading capacity, is to fulfill the limitation of vibration velocity of the floor required by the press manufacturer. Spring isolators with damping behavior are used to support the floating floor for reducing the vibration response caused by rotary printing press.

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The length and width of the floating floor are 23.6 meters and 8.4 meters, respectively. Figure 1 shows the plan of the floating floor and distribution of presses. It also shows the arrangement of spring units that will be described further in the next section. Figure 2 shows a typical cross section of the floor. The geometry of the cross section is designed to accommodate the press units within the limited height of the existing structure. The mass distribution and dynamic characteristic of press units were provided by the press manufacturer, and spring stiffness and damping coefficients were obtained from the spring supplier. Commercially available finite element program SAP2000 was applied for analysis and design.

This paper first describes details of numerical analyses and design. Subsequently, results of measurements of vibration behavior during operation of press are presented and compared with those of numerical analyses.

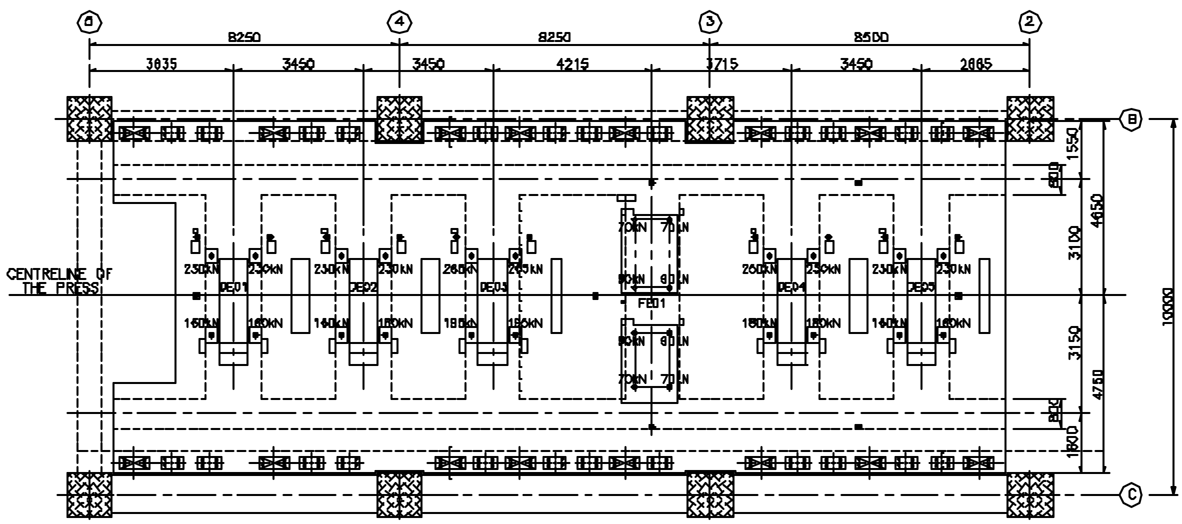

Figure 1. Plan of floor and distribution of presses

2. NUMERICAL MODEL

Prior to presenting the results of numerical analyses, information is provided on the numerical models. Finite element program SAP2000 was applied for analysis and design. Frame elements were used to simulate reinforced concrete girders and beams, and four-node quadrilateral shell elements with plate bending behavior were used for the reinforced concrete floor. Spring units were simulated by spring elements. Figure 3 shows the numerical model. The damping force is proportional to the velocity, and the dynamic response is thus linear.

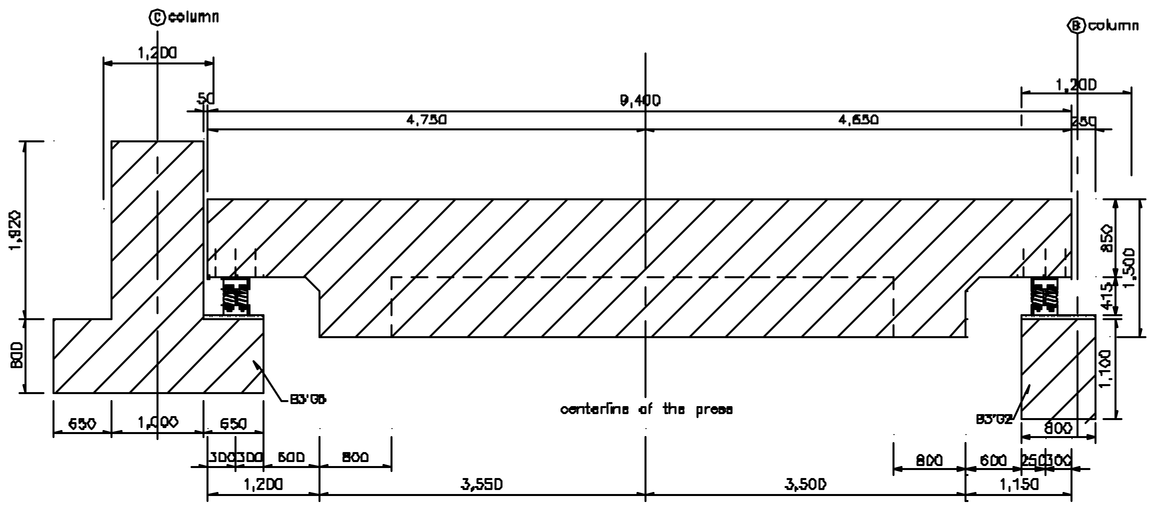

Figure 2. Typical cross section of floor

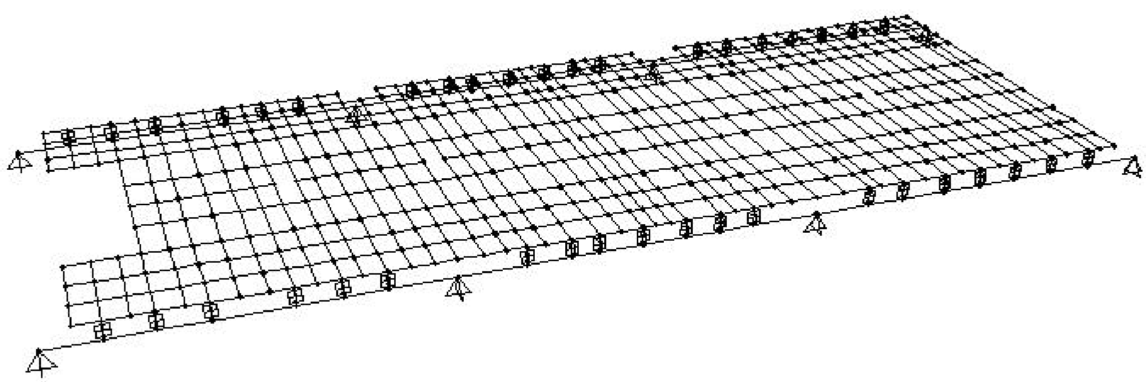

Figure 3. Finite element model of spring-supported floor

Press unit is distributed to the fixing points of the unit with lumped mass. Mass moment of inertia of the unit is taken into consideration. The mass distribution of press units was provided by the press manufacturer.

Two types of spring units are used to support the floor, namely GP and GPVM. Both types have the same stiffness, however, the GPVM type provides additional viscoelastic damping. The vertical and horizontal stiffness of spring units are 7.09 kN/mm and 4.38 kN/mm, respectively. The GPVM has a vertical damping coefficient of 255 kN.sec/m and a horizontal damping coefficient of 240 kN.sec/m.

The values of density, Young's modulus of elasticity, and Poisson's ratio used to define the material model for reinforced concrete floor were 2400 kg/m^3, 27529 MPa, and 0.2, respectively. The Young's modulus of elasticity of 27529 MPa corresponds to the concrete compressive strength fc' of 350 kg/cm^2 according to the approximate equation in ACI 318-95.

The responses of the system in the cases of resonance and forced vibration at maximum press speed were analyzed, respectively. Linear time history analyses were performed. In the analyses, point loads with time histories defined by continuous sine curves having specific frequencies and amplitudes are applied to the plate. Time histories of velocity at selected points are obtained, which simulate the response on the plate during the operation of the press. Dynamic load in the press provided by the press manufacturer is shown in the following table:

Table 1:Dynamic Load of Press

ORDER GROUP	FACTOR OF THE ORDER	POINT OF ACTION	f_{max} Hz	F_{max} N	DIRECTION OF THE ACTION
A	1	DE(2)	9.72	4160	LONGITUDINAL(X) VERTICAL(Z)
		FE(3)	9.72	600	VERTICAL(Z) TRANSVERSE(Y)
B	0.408	DE(2)	3.97	235	TRANSVERSE(Y)

NOTES:

1. The factor of an order is defined as follows: f_{max}/ $f_{max,cyl}$. Here f_{max}=max. frequency of an order, $f_{max,cyl}$=max. frequency of the plate cylinder.
2. The exciting forces are assigned to different orders. The unbalanced force of the plate cylinder has always the order 1. More orders exist, but they are negligible referring to DIN 4024 and not specified in the table.
3. The amplitude F_{max} of an order is calculated at the max. frequency fmax according to the max. press speed n=35000 r.p.h. in worst case.
4. The force increases quadratic with the exciting frequency:

$F(f)=F_{max}(f/f_{max})^2$

Here

f(Hz)=exciting frequency

f_{max}(Hz)=max. exciting frequency

F_{max}(N)=max. amplitude at f_{max}

F(f)(N)=amplitude at frequency f

3. RESPONSE OF THE SPRING SUPPORTED FLOOR

According to the specification of press manufacturer, the r.m.s value (root means square value) of velocity is used to evaluate the dynamic behavior. The r.m.s. value is calculated as follows:

$V_{rms}=V_{peak}/(2)^{1/2}$ =0.707 V_{peak}

where V_{peak} is critical vibration velocity obtained from analyses.

The r.m.s. value V_{rms} should not exceed 2.5 mm/sec in longitudinal (X-) and vertical (Z-) directions, 2.0 mm/sec in transverse (Y-) direction.

For the case of critical resonance vibration, eigenvalue analyses of the system were first preformed. The frequencies of the first nine modes range from 0.13 Hz to 9.24 Hz. These modes include rigid body displacement mode, rotational mode, couple mode, etc. A series of analyses with these exciting frequencies and corresponding load amplitudes as specified in the previous section were performed. The results show that the case of exciting frequency 9.24 Hz in Order Group A generates maximum vibration velocities at fixed points of FE01. The r.m.s velocities in longitudinal (X-) direction and vertical (Z-) direction are 0.63 mm/sec and 1.17 mm/sec, which is the less than the allowable value of 2.5 mm/sec. The r.m.s. velocity in transverse direction (Y-) is 0.08 mm/sec and is also less than the allowable value of 2.0 mm/sec.

In the case of forced vibration at maximum exciting frequencies (9.72 Hz for Order Group A and 3.97 Hz for Order Group B), the resulting longitudinal (X-), vertical (Z-), and transverse (Y-) r.m.s. velocities are 0.67, 1.23, 0.10 mm/sec for Order Group A and are 0.01, 0.16, 0.12 mm/sec for Order Group B. The vibration velocities in both Order Groups do not exceed allowable values. Velocities generated by Order group A have similar magnitudes as those in resonance vibration.

Vibration velocities obtained in forced vibration are compared with results of site measurement described in the next section.

4. RESULTS OF SITE MEASUREMENTS AND DISCUSSIONS

On-site measurement was performed to obtain vibration velocity at fixed points of FE01. The operation condition of presses was relatively close to Order Group A in numerical analyses where forces act in three perpendicular directions simultaneously at the highest speed. The measured longitudinal (X-), vertical (Z-), and transverse (Y-) velocities are 0.5, 0.3, and 0.3 mm/sec, respectively. The results show that the measured vibration velocities are in the same order of magnitude as analyzed results. The possible causes of difference are:

(1) The press unit DE05 (extension unit) was not installed and put into operation when the measurement was taken;

(2) Simplified applied force model used to estimate the response does not reflect the real force actions during operation; and,

(3) Mass distribution of auxiliary equipment was not considered in numerical analysis.

5. CONCLUSIONS

The studies described in this paper show that linear time history finite element analyses performed provide a conservative evaluation of vibration velocities of spring-supported concrete floor for presses. The performance of the structural system fulfills the requirement of high standard printing quality.

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