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PREDICTION OF FAILURES IN BUILDINGS USING SENSORS

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ABSTRACT

The paper deals with the prediction of failure in flexural members such as beams when subjected to overloading condition due to live loads, vibrations…etc,. The sensors are installed in the member to predict the failure. When the permissible deflections are exceeded due to loading on the member the sensors will give an earlier warning of collapse in the form of an alarm.

KEYWORDS: sensor, deflection, flexural members, kit box.

INTRODUCTION

Deflection forms one of the important criteria of assessing the performance of a structure under service load conditions. In the past, when working stress method, which is based on elastic theory, was principally used in R.C. design, the criterion for deflection was considered to have been satisfied merely by limiting the span depth ratio, because in elastic theory deflection is a direct function of load. With the use of ultimate strength method of design which recognizes the additional strength of member in inelastic range, sections work out to be slender and deflect more as compared to those obtained by working stress design. The time dependent factors like creep and shrinkage further increase the deflections under sustained load. This may result in successive deflections which may not be detrimental to safety of the structure but may considerably affect the serviceability of the structure and also the load distribution among the interconnected members.

SEVICEABILITY REQUIREMENTS FOR CONTROL OF DEFLECTIONS

Types of deflections

The study of the types of damages and their causes, and the knowledge of behavior on the reinforced concrete members under loads showed that the deflections of R.C. structures could be divided into following categories.

i. Short-term (or instantaneous or immediate) deflection due to initial elastic deformation of the member under the dead load and permanent imposed load service conditions. This type of deflection leads to bad effect.
ii. Long-term deflection due to creep and shrinkage under sustained load and additional short-term (elastic) deflection due to temporary live loads. This type of deflection leads to bad effects.
iii. The total deflection including short-term and long-term deflections. This is the quantity requiring overall control.

Allowable Deflections

The allowable deflection is governed by the serviceability requirements of a structure which may vary depending upon the type of structure, functional requirements of component members, severity of consequences of crossing the deflection limits etc. determination of acceptable deflection for varied types of structures and varied conditions is difficult. It needs large amount of statistical data about the damages caused by excessive deflections of guidance. Practically very little data is available at present. Inspite of this, there is no doubt that the rational values of permissible deflections have to be specified. This may be done on the basis of past experience, judgement and whatever data is available considering the various bad effects of deflection.

The codes, in general, express the allowable deflections in terms of span divided by an integer constant, this is because the span is the principal factor governing the magnitude of deflection(deflection varies with the cube of span).

The allowable deflection to span ratios for some of the more commonly occurring situations requiring deflection control may be taken as follows.

Total Deflection

From the study based on testing of structures, a committee of the institution of Structural Engineers (64/4) has recommended a limit of L/250 for total deflections.

Deflections occurring after the erection of partition walls

The limit for these deflections depends upon the flexibility and brittleness of partition walls. ACI committee-435 on deflections (68/6) has proposed following values.

i. Floors supporting non-structural elements not likely to be damaged by large deflections (e.g. flexible partitions, wooden partitions) L/350 or 20mm whichever is less.
ii. Floors supporting non-structural elements likely to be damaged by large deflections (compact partitions like thin brick walls) L/600 or 20mm whichever is less.

THEORY ON SETUP

This is an arrangement to be installed in every building considering safety against any casualty and the building itself. The setup is designed in such a way that any over load coming on the structure will be easily detected and indicated. A structure subjected to overloading due to various reasons may lead to deflection in the underlying structural members causing damage to the building. The sensors fabricated in this work ensures safety in the form of prior warning against collapse. This methodology to anticipate the failure in structures due to excessive deflection can be extensively used in laboratory studies and field investigation.

Laboratory Setup

In Laboratory those who using the setup will be very well known about the design (before carryout the test) since the concept involved in this setup is great deal in arrangement of the sensors. According to the deflection value obtained with respect to each increment of load sensors should be arranged. Figure 1.2 clearly illustrates the laboratory arrangement of the setup.

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Figure 1.2: Laboratory Setup

Following steps will explain you about the arrangement of sensors,

a) Calculate and obtain deflection value for such points like (permissible load, ultimate load, load before collapse, collapse load)
b) Arrange the sensors in Array in circuit board, such that sensor following in a row will work for single deflection value.
c) Arrange the sensors array in calculated deflection values that will double the times of mid span values.
d) Place the sensor circuit board vertically to the laser beam at end of the span.
e) Fix the laser beam gun (bottom) in a distance L/4 of effective span because there after angle formed with respect to horizontal line by given load with the corresponding deflection will be more.

The deflection can be calculated by the formulae,

$$\delta(P) = PL^3/48EI \quad N/mm^2 \qquad (1)$$

Switch on the kit box and apply the load. Now, when the beam begins to deflect, laser beam points the sensors and simulates the sensor circuit board. When the beam deflects, the corresponding load will be noted. The First stage of collapse due to deflection of the beam is presented in figure 1.3

Figure 1.3: Kit Box with Laboratory Setup

Field Setup

Schematic picture of the setup is shown in figure 1.4.

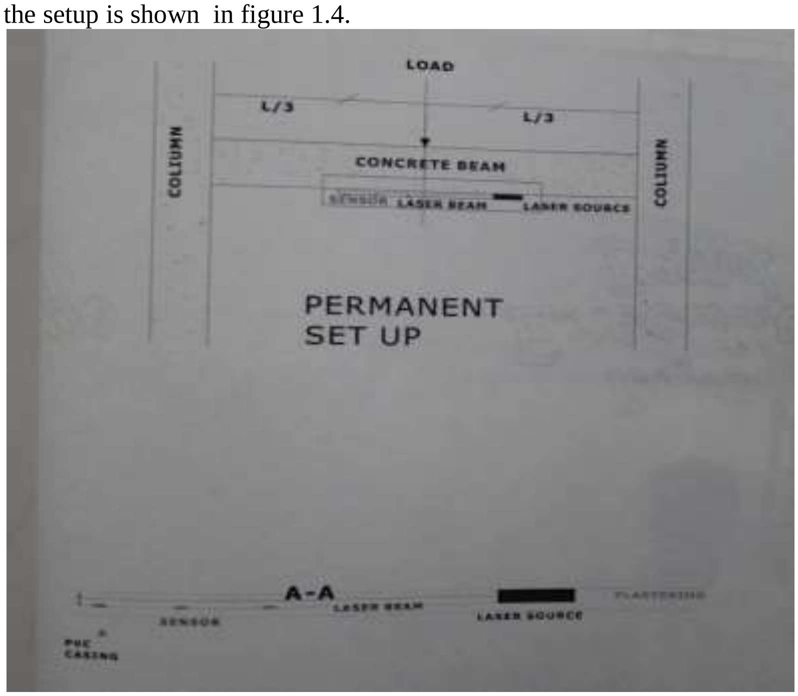

Figure 1.4: Permanent Field Setup

0.25 inch P.V.C pipe is fixed at the bottom of the beam as shown in figure 1.4 .When the beam begins to deflect then the laser beam will trace the path inside the P.V.C pipe. Following steps will guide regarding the placement of sensors.

1) Calculate the deflection for every load.
2) For any given load, D will be the deflection at the mid span of the beam.
3) 2D will be its corresponding deflection at the end of the effective span with distance L_1.
4) $2D/L_1 = 2D_1 / L_1$.
5) By fixing the $2D_1$ value, L2 can be easily calculated.
6) Repeat step no. 5 for any deflection values say $2D_n$ and obtain the corresponding L_n values.
7) Fix the sensors in the inner surface of the pipe at several points as per calculated deflection and distance.
8) For any unexpected load conditions if the flexural member is subjected to any deflection, it will be indicated by the setup.

KIT BOX

The Kit box contains LED with corresponding sensors attached to the beam. If the number of sensors increases correspondingly LED also will also be increased such as to indicate. When an LED begins to glow, respective buzzers will also be activated to alert the condition. When the buzzer is activated it will be kept active till the laser beam traces the next point of sensor to indicate the next stage of deflection or load. If number of sensors increases correspondingly circuit buzzers relay and transformer should be increased.

Figure 1.5 will illustrate the components of the kit box.

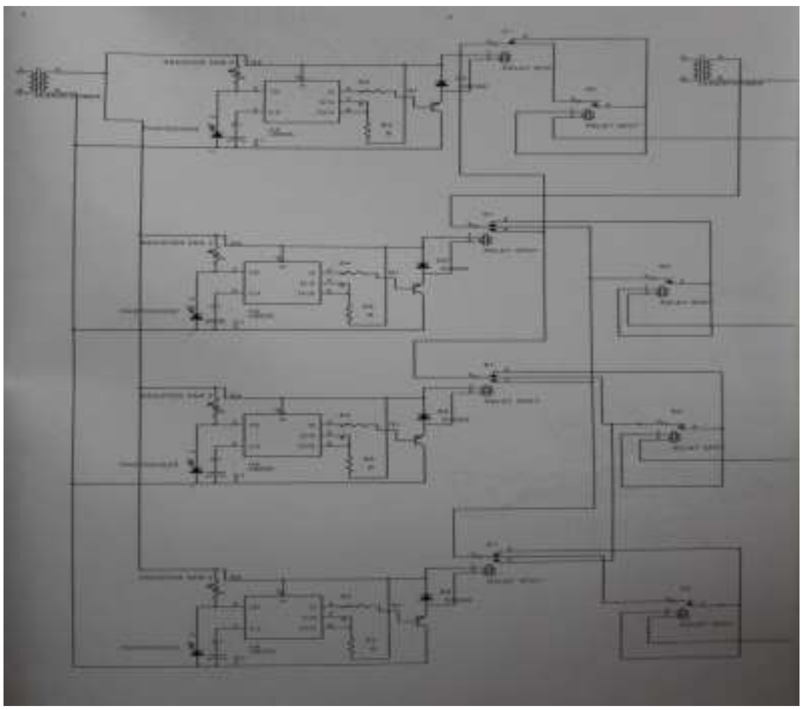

Figure 1.5: Circuit in the Kit box

RESULT AND COMPARISONS

Table 1 gives the comparison of load and deflections obtained using the theoretical and Practical approach.

Sensor Accuracy, δ = 0.2 mm
Resolution = 780 nm
Laser beam width = 3 mm
Where,
P= Permissible load C= Collapse load
U= Ultimate load WC= Worst combination of load

Table 1: Comparison of load and deflection

THEORITICAL APPROACH			PRACTICAL APPROACH	
DESCRIPTION	LOAD (N)	DEFLECTION δ mm	LOAD (N)	DEFLECTION δ mm
P	9810	1.33	8321	1.13
U	28160	3.86	26657	3.62
WC	47374	6.43	45874	6.23
C	66588	9.04	65094	8.84

CONCLUSIONS

The collapse of the structure causes damage not only to the building but also leads to causalities. Even though the sudden collapse cannot be predicted certain suggestive precautions can be taken to get an early warning.

In this project a specially fabricated sensor has identified the failure of the flexural member due to excessive deflection. The permissible value of the deflection experienced by the member is sensed and it gives an early warning in the form of an alarm before collapse. Such a device proves to be much useful in real field applications.

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