# DEVELOPMENT OF METHODOLOGY OF TESTING OF MULTI-STOREY PARKING GARAGES

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**Abstract**: *A proposal of methodology for experimental investigation of multi-storey parking garages is presented. Analysis has shown that only factors that are to be investigated are dead weight of structure and load weight. The paper describes analytical basis and results of calculations that lead to determination of critical points of structure where stresses are to be experimentally measured.*

**Key words**: *mechanical structures, testing, multi-storey parking garages*

## INTRODUCTION

Rapid development of Serbian cities and towns caused by increase of population during last decade stressed problem with car parking space and urged need for building of multi-storey car garages, well-known to the rest of the world [1]. Increase of the demand made use of prefabricated components preferable choice in many cities (Belgrade, Novi Sad, etc). The components were imported from Italy and the fact motivated Serbian engineers to develop their own concept of multi-storey garages, which resulted in project "New solution of modular metallic multi-storey garage", financed by Ministry of Science and Technology of Republic of Serbia. The main idea of the concept is application of steel-made components instead of concrete, which makes garage structure lighter and enhances modularity of solution.

A new concept of structure requests also development of methodology for its testing, being that previous experiences in exploitation of the garages, or national legislation on the point do not exist.

This paper describes basis, concepts and proposed methodology for testing of multi-storey garages. The developed concept may also be utilized for other types of multi-storey garages made from prefabricated elements.

## BASIS

The basis for development of methodology of investigation of multi-storey car parks is assumption that dead weight of structure and weight of load are factors which influences should be investigated by experiment in testing process. Seismic influence on structures of similar type is already known and may be calculated and estimated through developed procedures [2] and temperature influence may be neglected. One additional factor that was considered was the influence of the wind in case that outer side of garages is used for advertising panels. However, this cannot be considered as inherent influence to the structure being that its basic design does not include it, and this influence needs to be considered only in case that customer makes such request.

The basis for development of methodology for estimation of the influence of dead weight and load weight is calculation of stresses in garage structure. The calculation showed critical points that are exposed to highest levels of stress. Testing procedure comprises measurement of actual stresses at these points under selected loading conditions.

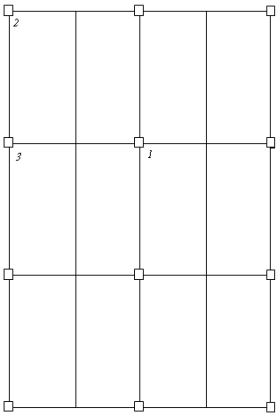


Fig 1. Schematic drawing of a floor of one garage level

All measurements that are to be performed are static, although exploitation conditions (loading and unloading during car parking processes) are essentially quasi-static. However, being that characteristic times of parking processes are much longer than relaxation processes of metallic structure, it is estimated that no dynamic measurements are needed.

Figure 1 presents schematic drawing of garage floor where large rectangles represent parking places and little

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squares (at corners of the rectangles) represent structure columns. Lines represent structure bearers. Three characteristic columns are marked by numbers: 1-column at inner intersection of bearers, 2-column at the corner of garage structure and 3-column at outer intersection of bearers, but still not at corner of structure.

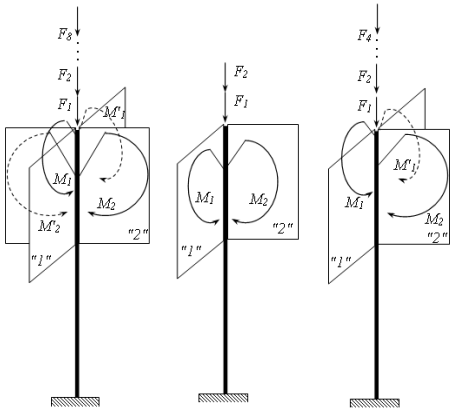


Fig.2. Basic static loads of selected columns
left-column 1, middle-column 2 and right-column 3

Basic static loads, resulting from static analysis, are shown at Figure 2. Column at position 1 has highest vertical loads, but bending moments acting on the column are of opposite signs and are being partially cancelled. Column at position 2 has the lowest vertical loads, but bending moments acting on it are the highest. Columns at position 3 have loads which are combination of two previous cases-vertical loads are lower compared to columns at position 1, but higher then at columns at position 2; bending moments acting on them are partially canceling each other in one plane, but in other plane there is no cancellation.

On basis of thus determined basic loads, calculation of stresses is performed by application of finite element method software. The calculation showed critical points at columns and bearers: at columns the highest stresses are expected at their top, and for bearers at joints.

## PROPOSED METHOD

It is important to stress that, according to calculations, that dead weight of construction causes significant stresses (it holds especially for cases when structure includes some concrete parts). Therefore, stress measurements should reveal dead weight stresses as well.

Therefore, the proposed methodology for testing of multi-storage garages is the following:

1. Stresses are to be measured at points belonging to one parking cell which is at corner of parking; measuring points are at top of columns indicated by numbers 1, 2 and 3 and at joints of middle bearer of the cell.
2. As zero level of investigated stresses is considered level of stress that is existing in prefabricated elements before they are mounted in structure. All activities that are to be performed in order to determine zero-level of stresses (strain gauges sealing, measurements of initial voltage levels, etc) are to be performed before mounting;
3. Stresses caused by dead weight of structure at measurement points are to be measured while garage is empty.
4. Stresses caused by load are to be measured by parking cars at both parking places.
5. Stresses at all measurement points are to be lower than allowed level for material of structure.

## CONCLUSION

Developed methodology takes into account dead weight induced stresses and load induced stresses, and comprises measurement of stresses at five critical points of structure. Although number of measuring points is low, serious measurement skills are needed in order to provide accurate and trustable results, considering the fact that standard measurement procedures for investigation of mechanical structures rely on measurement of zero-level stresses immediately before stress is applied, which in this case is not possible.

In process of development of testing methodology no assumptions were made except its geometric characteristics. Therefore, the developed testing procedure may be applied to any type of multi-storey parking garages with the same geometry.

## LITERATURE

[1] Jane Holtz Kay, "A Brief History of Parking: The Life and After-life of Paving the Planet", Architecture Magazine, February 2001.
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