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Ceilbot-project

REPORT

9.12.2009

Ceiling structures

Goal of the structural engineering in this project was to study the ceiling structures and determine their suitability for ceilbot fixation. Used methods were studied with other project members including different possible operation environments where robot could be used. During the project suitable information was collected from literature about materials and structures used in possible operation environments.

In project team meetings, ceiling structure possibilities, structural limits and risks for robot usage, were discussed. During meetings structural details and properties were described. Typical loads and stresses to ceiling were introduced from civil engineering point of view. Finally the introduction for general methods of safe installation and fastener design were presented.

History

Before 19th century ceilings were used in ancient castle's and churches and made of timber or masonry. During 19th century cast iron, steel and concrete were also used.

Old ceilings were done by craftsmen and were supposed to carry mainly its own weight. During the centuries quality and construction methods varied a lot.

Today

Ceiling is nowadays common element in most buildings. In residential buildings ceiling is situated usually in washrooms and

hallways, where installations needs to be hidden. In office buildings ceiling is usually in large areas and hide structures and installations. Small family houses, day-cares, warehouses and even some industrial buildings timber structures and ceilings are used widely.

Today ceiling is usually hanging from load bearing structure by fasteners. Building regulations (etc. fire regulations) defines materials that are allowed to use in particular buildings.

Loading

Loading assumptions are given in design codes which are usually national. In Finland a new design code, Eurocode with National Annexes, were taken in use November 2007.

Loading for structures supporting the ceiling consist of own weight, live load and ceiling load. These loads are resulting mainly in vertical direction. Installations can cause three-dimensional loads, which are handled separately (superposition) in basic structural calculations.

Dynamic excitations and loading for ceiling is caused by use (etc. walking), installations and machinery. Often natural frequencies in ceilings and structures which supports it, are low, and risk of resonance should be paid attention. In case of ceilbot, both passive and active dampings are possible for reducing harmful vibrations.

Use of robot can cause structure-borne and airborne sounds, which should be avoided by insulating robot fixing points from the structure. In the market there are various damping systems which can be used to verify proper robot installation.

Walls

Walls are normally preventing robot usage by limiting robots route inside the building. Walls can have several functionalities in

building, etc. load bearing, partition, and stiffening. Concrete, masonry, timber and steel profiles are widely used for wall primary material. Walls can be covered by different boards and sheeting's.

Robot route through wall causes usually new holes and should be examined by structural engineer. In residential buildings new holes in load bearing walls causes limitations of upper and lower neighbour flats, which must have approval from housing association.

Sports halls

Need for long spans and large open space is determining sports hall structures. Resulting that demand primary structural geometry is usually arches, domes, trusses and cable structures. Material used in sports hall is steel, laminated timber or veneer or concrete. Ceiling, if any, is in most cases supported from secondary structures as beams, trusses, slabs and steel sheeting.

Noticeable for robot attachment is the large system movements caused from deflection, creep, moisture and temperature changes. Because of the height of the structure, robot and possible railing system maintenance routes should be planned carefully and safety aspects should be foreseen in early phase of designing.

Fasteners

Ceiling is fastened to load bearing structure by fasteners and anchors. Fasteners and anchors carry mainly vertical dead loads from ceiling and attached equipment. Unless rules are given in design codes, characteristic values for anchors capacity, stiffness and fire properties must be determined by testing. All fasteners and anchors which are strained dynamically or are under fatigue should be approved for such purpose. Anchors for permanent use must have test results for fire resistance or approved method for fire protection.

Base material is playing a decisive role for selecting the fastener. In concrete basic holding principles are friction, keying and bonding. In timber structure basic holding principles are shear, tension and compression. Different building materials provide different conditions for anchors. Material characteristics and installation faults causes reduction for anchor capacity.

Risks

Overloading and wrong material choices could be fatal and may cause serious damages and even loss of life's. Fasteners must act safe and should be tested properly. All fastenings should be designed so that they are easy to check and if necessary maintain or replace. Connecting installation system, etc. robot, design boundaries and responsibilities should be verified, so there will not be information break between designers and suppliers.

Conclusions

Ceilbot is possible to install to ceiling structures. New applied loads from robot installation should be able to distribute as uniform as possible. This will provide lowest point loads to the structure and fixings. However, because there are different ceiling types and materials there needs to be customization in the connection system. Analysing the optimum connection solutions needs more information from robot development.

Recommendations for further studies

Further profound structural research should be performed for robot fastening points in most common materials from three different views: static, dynamic and sound.

In spots hall environment more in-depth study for limitations of ceilbot usage in different structural framing systems is recommended.

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