Loading Conditions in Analysis Models

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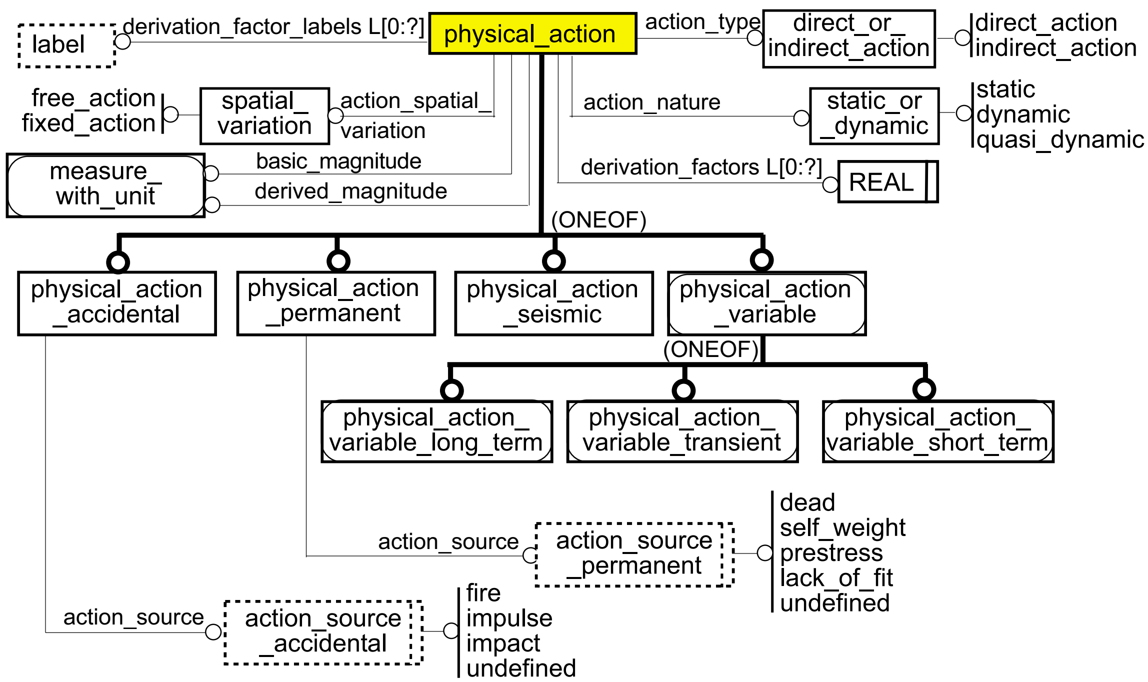
Introduction

This tutorial reviews the organization of structural loading conditions and their application to nodes and elements in analysis models. It also addresses how these can be associated with a design model.

Physical action

Loads define the physical forces acting upon a structure. They may be due to the live loads that the structure carries, wind loads, seismic, as the result of accidents, termprary loads during construction and others. The condition a load is defined to respond to are defined as a physical_action in CIS/2, and represented as shown in Figure One.



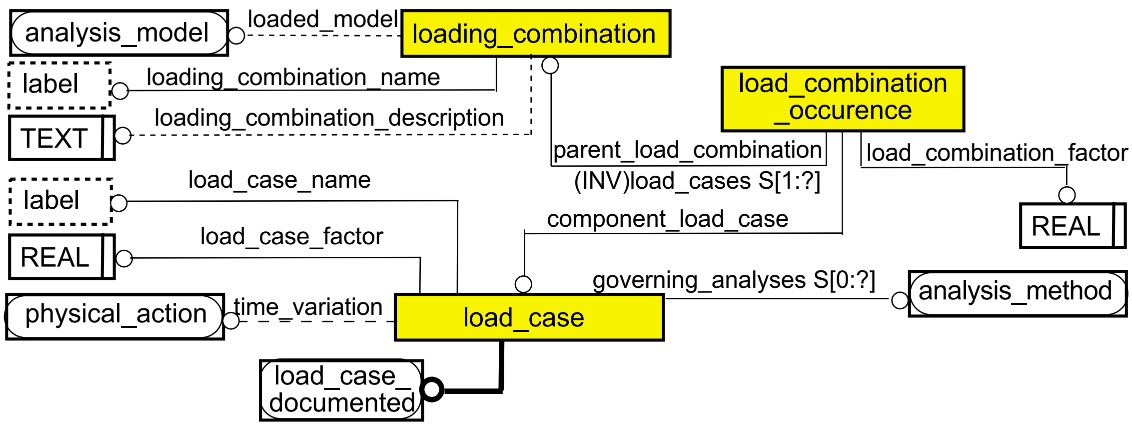
A general physical_action is classified as direct or indirect, as static or dynamic, as free_action or fixed_action. It has a magnitude and derivation_factors and corresponding labels. The derivation_factors identify the factors applied to the basic_magnitude load to derive the derived_magnitude loads. A physical_action may be subclassed to identify the action as an accidental, permanent, seismic or variable action. Physical_actions may be defned aprioria, then applied to various load_cases as needed. Multiple types of physical actions may be defined, using the various subclasses.

An example of the attributes carried in a physical_action can be seen when we flatten the structure of one of them, say physical_action_permanent, as shown below. Notice that physical_action_permanent adds a single additional attribute, as does physical_action_accidental.

The WHERE clause requires the number of derivation_factors to be the same as the number of derivation_factor_labels.

Load Case

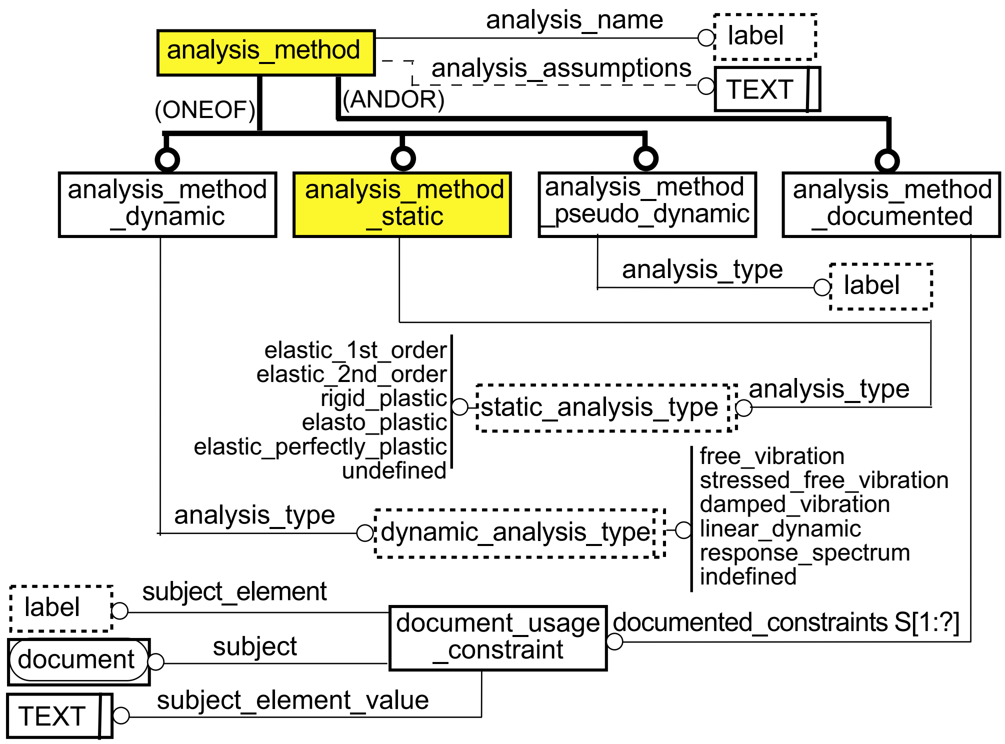
A physical_action is used to describe a load_case, which is a set of loads and the phenomena the loads represent. The corresponding structure is shown in Figure Two. Each load_case has a name and a load_case_factor and one or more governing_analysis.



The set of loads associated with a load_case is referenced by a load_combination_occurance, which also applies a factor. Load_case_occurances are grouped into loading_combinations, addressing for example live and wind loads. The optional ANDOR subclass load_case_ documented provides a reference to the code section that the load case is based on.

Analysis Method

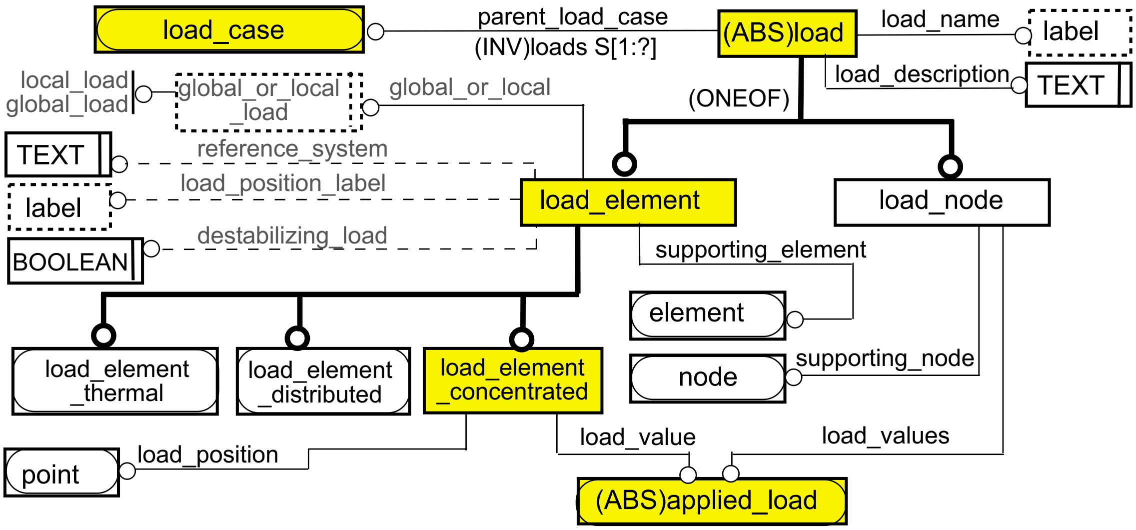
A physical_action describes the real-world basis for the load case, which must be translated into a method of analysis, characterized in analysis_method. The contents of analysis_method is shown in Figure Three. Analysis_method is described by assumptions and a name. It has one of three subclasses: static, dynamic, pseudo-dynamic; each characterizes the analysis method intended. Any of these carry an associated document and constraint, using the ANDOR clause. The different subclasses of analysis_method add specialized attributes. Using the optional ANDOR subclass analysis_method_documented, the analysis method can have a reference to the code section specifying the method.



An example of the flattened structure describing a common analysis method is analysis_method_simple, shown below.

Loads

Load cases are made up of individual loads applied to elements and nodes. The CIS/2 structures for defining and applying individual loads is shown in Figure Four. Each load is subclassed into a load_node or load_element and has a name and description. These associate one load with an element or node. Of course, multiple loads may be applied to these entities. While load_nodes are always concentrated, load_elements may be concentrated or distributed (or thermal), defined as subclasses. Load_distributed, not detailed here, addresses loads distributed over a line or a surface. Each has an optional name, a textual description of its reference system, a flag whether it is destabilizing (.TRUE.) or not and a designation as a local or global load.

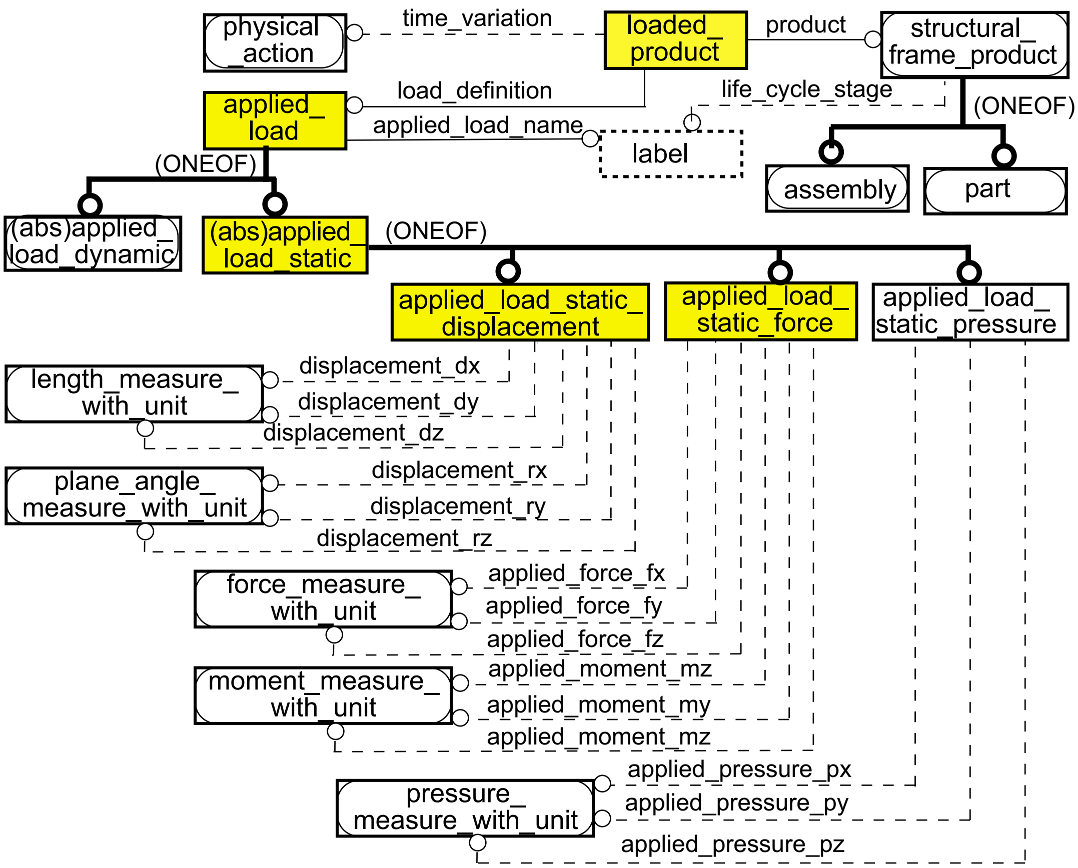


An example detail specification of a load might be a load_element_concentrated, which inherits attributes from load_element and load:

The WHERE clause prohibits the applied_load from being of subclass type applied_load_static_pressure.

Applied Load

Applied_load is the actual load that is applied to an element or node. Its structure is shown in Figure Five. It is subclassed into either an applied_load_static or applied_load_dynamic, both of which have further subclasses. Here we look at applied_load_static subclasses.



Displacement loads are defined with three displacement variables in x, y, and z and three rotations about the three axes. A force load has three forces and three moments. Taken together, the flattened applied_load_static_force has the Express definition:

As can be seen, applied_load and applied_load_static are primarily a way to group subclasses and add little to the entity definitions. The forces and moments are all optional, allowing only significant loads to be defined. The WHERE clause, however, requires that all forces and moments not be omitted.

Loads may be defined once and used several times and in several places, for example in repeated, equally spaced cross members.

Associating Loads with Design Members

Up until now, the description of loads has focused on their association with elements and nodes in an analysis model. Each loading_combination is optionally associated with an analysis_model. However, an applied_load can also be associated with a structural_frame_product , and its subtypes, part or assembly.

The CIS/2 structures support the association of loads with design_parts are also shown in Figure Five. The central entity is loaded_product. It associates a structural_frame_product with an applied_load, and optionally with a physical_action. It must be kept in mind that a structural_frame_product may be a generic item, referenced by multiple design_parts or located_parts at the individual level. This must be considered as applied_loads are assigned.

The loads associated with a structural_frame_product are likely to be distinct from those associated with corresponding elements, if only because they aggregate loads across several elements. Because multiple loaded_product associations may be defined for a single structural_ frame_product, one can associate with it multiple applied_loads, indicating the different element loads corresponding to a member.