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Deflections

Many difficulties develop in buildings as the result of deflections of spanning members, which sometimes are in excess of those allowed for by designers. It is thought that excessive rotation at end joints, or differential deflections between slabs of precast materials can be the cause of roof membrane cracking in some cases. With all types of concrete decks creep deflection will result in depressions on the roof, which will interfere with drainage and subject the roofing membrane to accelerated deterioration. With some forms of light-weight deck and particularly steel, the springiness of the deck during application can also present problems, with the possibility of damage to roofing materials during the construction operations. Thin plywood roof sheathing that may be entirely satisfactory structurally, for instance, may be unsuitable for application of roof shingles by nailing and deflection may give an undesirable visual effect.

When a spanning member, a beam or a roof slab is subjected to a load, it tends to sag or takes on a downward curvature called deflection. The top portion is put into compression and tends to shorten, and the lower portion is subjected to tension and tends to lengthen. The ends at the supports tend to go up as the centre of the member goes down, depending on the amount of restraint at the support. The weight of the member itself, and the rest of the roof system resting on it or hung from it, constitutes a continuing loading called the dead load, which can cause materials like concrete to "plastic flow" or creep, producing deflection that can be several times the deflection allowed for in design due to snow load or design load. Creep deflection should be considered for all concrete materials. It may be involved with wood structures, but normally can be disregarded for steel spanning members.

The designer can determine the maximum deflection to be expected by precise or approximate methods for any particular structural roof system, and by modifications to the design can limit the amount of deflection. There may be some difficulty however in deciding on what is the amount of deflection that can be allowed. Statements on allowable values of deflection are normally related to span, and a usual one is that it should be L/360 of the span. Surprisingly enough, there is very little information available on which to judge the rationality of such a rule, except that it is customary and has worked reasonably well in the past. In those buildings in which significant deflections develop, the actual values and their effects are seldom measured and recorded, except where they are flagrantly in excess of tolerable values.

The above mentioned ratio of L/360 (L being span) has been a traditional limit for deflections, although its origin is not widely known. The principle of limiting deflection in proportion to the span appears to have begun with Tredgold, a famous engineer born in 1788, who was one of the first to establish and publish criteria for the design of flexural members. He recognized that permissible deflections should be proportional to the length of the member and recommended a limit of L/480. Later in the 19th century, American engineers increased the allowable deflection to L/360 for houses.

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Bearing in mind that materials and construction methods today are quite different from those in 1850, there is little in the way of factual information to indicate whether L/360 is still an appropriate limit. Such laboratory tests and studies as there are indicate that with regard to plaster and masonry cracking, visibility of sags and springiness of floors, the traditional L/360 is adequate for normal cases but is just barely so. It offers no guarantee that plaster will not crack, and part of its success has been due to the fact that buildings seldom receive their full design loads, that there is load sharing among the members and that although cracks do occur they sometimes cause no further trouble when patched. Where greater assurance is wanted that cracks will not occur, the total deflection limit might profitably be reduced to L/480 or even L/720.

Larger deflections of the order of L/180 are often allowed for roofs having no finishing material on their undersides. There is considerable possibility that this may cause damage to the roofing, may interfere with proper drainage, and usually the resulting sagging will be clearly visible.

The allowable deflection for any situation should be established from a consideration of the material used and the associated construction, and for roofs this should include a consideration of the application of the roofing and the possibility of damage to the roofing membrane. For steel members L/360 is normally satisfactory because dead load deflections seldom contribute to deflection problems and design loads are seldom realized. The greatest portion of the total deflection in concrete members however is die to the permanent portion of the total load (the dead load). The allowable deflection of L/360 is only satisfactory when long term deflections resulting from creep, shrinkage and temperature effects have been included. The fact that the design load is seldom attained in service is of little significance in this case.

Provisions for deflection are included in the National Building code in Part 4 on design. In Section 4.3.4. the deflection of wood members is required not to exceed L/360 when calculated on the basis of live load only. Other deflection span ratios are allowed provided the characteristics of complimentary materials are not exceeded, and the limit is L/180 when calculated on the basis of live and dead loads combined.

For concrete the control of deflection is covered in Section 4.5.4.9. and it spells out the factors that should be considered. The maximum limits for immediate deflection due to live load are L/180 for roofs which do not support plastered ceilings and L/360 for roofs which do support plastered ceilings. For roof construction intended to be attached to partitions or other construction likely to be damaged by large deflections, the allowable limit for the sum of the immediate deflection under live load, and the additional deflection due to shrinkage and creep under dead load is limited to L/360.

For steel the requirements are covered under Section 4.6.11. It says that "If not otherwise specified, deflection due to live load shall not exceed L/240 of the span in roof beams, except that then such beams support a plastered ceiling or similar finish, the deflection due to live load shall not exceed L/360 of the span. Roofs having a pitch greater than 4 in 12 may have a deflection due to live load not exceeding L/180 of the span".