Design Live Loads for Parking Structure Decks

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A code change proposed and tentatively approved for the 2006 International Building Code would increase the minimum uniformly distributed design live load for passenger vehicle parking structure decks from a reduced 30 psf (1.4 kPa) to an unreduced 40 psf (1.9 kPa). The implications of this change and its justification, or lack thereof, are discussed in this article.

The Structural Code Committee of the International Code Council has made recommendations (approve as submitted, approve as modified, or decline) concerning changes proposed to the 2003 *International Building Code* including its 2004 Supplement. If no public comment is submitted on a particular change, Committee recommendation on that change automatically becomes final action. If a public comment is submitted, that will be heard and final action on the change concerned will be decided upon at the ICC Public Action Hearings this fall. At least one of the changes proposed for the 2006 IBC has significant implications for the precast/prestressed concrete industry and is the subject of this article. PCI has submitted a public comment on this change.

BACKGROUND

Prior to the publication of the first edition of the *International Building Code* (IBC)[1] in 2000, the building codes of various local jurisdictions (cities, counties, states) throughout the United States used to be based on one of three model codes that are now being called the "legacy" codes. These were *The BOCA National Building Code* (BOCA/NBC),[2] mostly used in the northeast, the *Standard Building Code* (SBC),[3] mostly used in the southeast, and the *Uniform Building Code* (UBC),[4] used in the rest of the country (roughly, the United States west of the Mississippi). Many local jurisdictions continue to use the legacy codes. The codes of all California jurisdictions, for instance, are still based on the 1997 UBC.

On the topic of live load reduction, the three legacy codes differed rather significantly from one another. The BOCA/NBC strictly followed the ASCE 7 Standard *Minimum Design Loads for Buildings and Other Structures*[5] and allowed live load reduction based on influence area. No live load reduction was allowed in parking garages or open parking structures, except that the design live load for members supporting more than one floor (columns and walls) could be reduced by up to 20 percent. The SBC allowed live load reduction of up to 40 percent for horizontal members and up to 60 percent for vertical members, based on tributary area. There was no particular restriction for parking structures.

The UBC contained the SBC provisions (live load reduction based on tributary area, no restriction for parking structures), and also the BOCA/NBC provision as an alternate (live load reduction based on influence area, no live load reduction for deck members in parking structures). The live load reduction provisions of the 2000 IBC were almost the same as those of the 1997 UBC. The alternate live load reduction of the UBC (based on influence area, no reduction for parking structure decks) became the "regular" reduction of the IBC. The "regular" live load reductions of the UBC (based on tributary area,

no restriction or reduction for parking structures) became the alternate live load reduction of the IBC.

The fairly significant implications of the above need to be understood. Under the legacy codes, in BOCA territory (roughly the northeastern quarter of the United States), parking structure decks had to be designed for a uniformly distributed live load of 50 psf (2.4 kPa) (unreduced), while in the rest of the country, the same decks could be designed for a reduced live load of 30 psf (1.4 kPa) [assuming a tributary area of at least 650 sq ft (60 m^2)]. The alternate live load reduction provisions of the 2000 IBC for the first time allowed parking structure decks in BOCA territory to be designed for reduced live loads of 30 psf (1.4 kPa).

2003 IBC AND 2004 SUPPLEMENT

In the 2002 edition of the ASCE 7 standard, the minimum uniformly distributed live load for passenger vehicle garage floors was decreased from 50 to 40 psf (2.4 to 1.9 kPa). This meant that, by taking advantage of alternate live load reduction, one could design parking structure floors for a reduced live load of 24 psf (1.1 kPa), which was totally unintended, since there is no experience concerning the performance of parking structure floors designed using a live load below 30 psf (1.4 kPa). In the 2004 Supplement to the 2003 IBC, this unintended consequence was addressed by specifying a minimum design live load of 30 psf (1.4 kPa).

CHANGE PROPOSED AND TENTATIVELY APPROVED FOR 2006 IBC

The live load reduction provisions of the 2006 IBC may be quite different because of Code Change S25-04/05 submitted by the General Engineering Subcommittee of the Code Advisory Committee of the National Council of Structural Engineers Associations, which was approved by the ICC Structural Code Committee at the ICC Code Development Hearings held in Cincinnati in February 2005. Code Change S25-04/05 adds the following restriction to 2003 IBC Section 1607.9.2, Alternate floor live load reduction: "A reduction shall not be permitted in passenger vehicle parking garages except the live loads for members supporting two or more floors are permitted to be reduced by a maximum 20 percent."

The submitted reason is reproduced below:

"S14-02, which was approved, lowered the floor live load in garages from 50 psf to 40 psf. Section 1607.9.1 Reduction in Live Loads – General has not permitted LL reduction in garages, but Section 1607.9.2 Alternate floor live load reduction does so. Code change S12-03/04 corrected a condition that would have allowed reduction of garage live load to 24 psf, down from the maximum reduction to 30 psf found in the legacy codes. However, this left a condition where 1607.9.1 did not allow live loads for floor members in garages to be reduced and 1607.9.2 allowed a 10 psf (15 percent) reduction for those same members. This code change applies the prohibition on reduction of live load on garage floor members to Section 1607.9.2 so that the provisions of both sections are the same in this regard."

DISCUSSION OF CHANGE

It should be obvious that the above change increases the design live load for parking structure decks from 30 to 40 psf (1.4 to 1.9 kPa) in much of the country where the UBC and the SBC were or still are in use (or where the IBC has already been adopted). The only justification given is consistency between 2003 IBC Sections 1607.9.2 and 1607.9.1, which basically means consistency with ASCE 7. Of course, consistency between Sections 1607.9.2 and 1607.9.1 can also be achieved by removing the restriction on live load reduction for parking structure deck members in Section 1607.9.1.

The reduction in the minimum uniformly distributed live load for passenger vehicle garage floors from 50 to 40 psf (2.4 to 1.9 kPa) from ASCE 7-98 to ASCE 7-02 lessens the impact of the proposed change, but should not be used as justification for the change.

The 50 psf (2.4 kPa) value represents roughly twice the maximum load that can be applied by the heaviest passenger vehicles parked in all spaces and aisles of a garage.[6,7] It reportedly included a 100 percent impact factor decided upon by the American National Standards Institute (ANSI).[6] Note that today's ASCE 7 standard was ANSI Standard A58.1 prior to its 1988 edition.

The design load combinations of ACI 318 changed from the 1999 to the 2002 edition of that standard. The basic gravity load combination changed from $1.4D + 1.7L$ to $1.2D + 1.6L$. Thus, the new load combinations yield lower design gravity loads than the old combinations. There have, however, been corresponding decreases in strength reduction factors, ϕ, except that the ϕ-factor remains unchanged at 0.9 for tension-controlled sections, which would include virtually all slab and beam sections. Therefore, flexural design of slabs and beams is more economical under ACI 318-02 than under prior editions of ACI 318.

While this provision also lessens the impact of a prohibition on live load reduction for parking garage deck members, the changes were made for totally unrelated reasons. The ϕ-factor for tension-controlled sections was kept at 0.9 partly because a new study at the University of Michigan, Ann Arbor, has shown that variabilities in the properties of ready-mixed concrete, reinforcing steel, and prestressing steel are significantly lower now than they used to be when the ϕ-factors of ACI 318 had originally been selected. Perhaps a more important reason was that if the ϕ-factor for tension-controlled sections is kept unchanged while all the other ϕ-factors are reduced, that would make ductile flexural tension failure preceding more brittle modes of failure more likely, thus resulting in a more desirable hierarchy of failure modes.

Incidentally, perhaps the most significant change in the design load combinations that affects the roof level in parking structures is that the design snow loads are now explicitly addressed, while that was not the case through the 1999 edition of ACI 318. Determining the combination of live and snow loads on parking structures used to be somewhat of a dilemma. Since the codes did not make the choice clear, the decision was left to the individual jurisdictions. In some jurisdictions, the decision was to require the full live and snow load combination. In those jurisdictions, the new load combination ($1.2D + 1.6L + 0.2S$) provides welcome relief.

SERVICEABILITY ASPECTS

The point was emphatically made by Logan[7] that the service behavior of a parking structure suffers because it is required to be designed to accommodate loads far in excess of those to which the structure will ever be subjected. In this context, it is worth quoting the following two paragraphs from Becker:[8]

"Prior to adopting IBC 2000, the State of Wisconsin had its own building code that required a 50 psf live load without any reduction for parking garages. We built numerous garages under that requirement. A recurring problem was differential camber between double tee units. With calculated cambers of 2 to 2½ in., the variability in actual cambers made it difficult to level the tees in the field to a ¼ in. tolerance. The result was ponding of water in drainage lines and noticeable irregularities in the driving aisles.

"With the adoption of IBC 2000, we had our first opportunity to reduce the live loads. The result was dramatic as calculated cambers reduced to 1 to 1½ in., differential cambers were reduced, and double tees could be leveled to less than ¼ in. differential. Ponding of water has been almost eliminated and the drive aisles provide a more acceptable driving surface."

CONCLUDING REMARKS

As noted above, Code Change S25-04/05 has been approved by the ICC Structural Code Committee. PCI has submitted a public comment which, if approved at the ICC Final Action Hearings to be held in Detroit in September 2005, will overturn this approval. Such an action would be in order because the only justification cited in favor of S25-04/05, which will increase the design live load for parking structure decks in much of the country from 30 to 40 psf (1.4 to 1.9 kPa), has been consistency with ASCE 7. No lack of safety or lack of performance of a parking structure owing to any insufficiency of the design live load of 30 psf (1.4 kPa) (which has long been in use) has ever been cited.

The decrease in the minimum uniformly distributed live load for parking structure floors from 50 to 40 psf (2.4 to 1.9 kPa) from ASCE 7-98 to ASCE 7-02 and changes in the design load combinations from ACI 318-99 to ACI 318-02 soften the impact of S25-04/05, but do not in any way justify that change.

It is also important to note that regression to a 40 psf (1.9 kPa) design live load will result in serviceability problems that affect the everyday use of a parking structure.

REFERENCES

1. ICC, *International Building Code*, International Code Council, Falls Church, VA, 2000, 2003.
2. BOCA, *The BOCA National Building Code*, Building Officials and Code Administrators International, Country Club Hills, IL, 1999.
3. SBC, *Standard Building Code*, Southern Building Code Congress International, Birmingham, AL, 1999.
4. ICBO, *Uniform Building Code*, V. II, International Conference of Building Officials, Whittier, CA, 1997.
5. ASCE, *ASCE 7 Standard Minimum Design Loads for Buildings and Other Structures*, Structural Engineering Institute, American Society of Civil Engineers, Reston, VA, 1998, 2002.
6. Prebis, W. J., "Designing for the Combination of Live Load and Snow Load in Parking Structures," PCI JOURNAL, V. 48, No. 2, March-April 2003, pp. 114-115.
7. Logan, D. R., "Combination Live Load and Snow Load in Parking Structures: Predict Realistic Loads to Control Service Performance," PCI JOURNAL, V. 48, No. 2, March-April 2003, p. 116.
8. Becker, R. J., Private Correspondence, February 2005.