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VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ FAKULTA STAVEBNÍ

Posudek disertační práce

Autor práce: **Josef Květoň**
Název práce: **Static and dynamic analysis of plain and fiber-reinforced concrete using discrete meso-scale model**
Studijní obor: **P3607 Civil Engineering (nDA)**

Oponent: **Prof. Ing. Michal Šejnoha, Ph.D., DSc.**
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Aktuálnost tématu disertační práce

Modeling of fiber reinforced concrete has been at the forefront of engineering interest for some time. A proper description of the processes taken place at the fiber scale is therefore inevitable and should positively support the design of such structures. Although not specifically mentioned, the application of fiber reinforced concrete in environment, where damage evolution due to, e.g. shock waves, play some role, is a natural extension promoted by modeling initiatives in the area of high speed loading also discussed in the thesis. The application of discrete particle modeling approach is expected to shed a light, at least qualitatively, on a number of issues associated with fiber reinforced concrete. Both topics discussed in the thesis thus deserve attention.

Hodnocení:

☐ vynikající	☒ nadprůměrné	☐ průměrné	☐ podprůměrné	☐ slabé

Splnění cílů disertační práce

The goals of the thesis were clearly identified in Section 1.3. The results presented in Chapters 6 and 9 indicate that most of the goals were successfully achieved. What I am missing is a clear indication of the authors own contribution in the field of discrete particle modeling. Although coding all the presented constitutive equations, taken mostly from literature, required a considerable effort and programming skills, I like to believe that the content of the thesis goes beyond that. However, this has not been sufficiently clarified. The author may wish to respond to this remark during the thesis defense.

Hodnocení:

☐ vynikající	☒ nadprůměrné	☐ průměrné	☐ podprůměrné	☐ slabé

Postup řešení problému – metody zpracování

The work is presented in 10 Chapters. The methodical and conceptual approaches are described in Chapters 3, 4, and 8 providing the theoretical grounds on general theory of discrete particle

modeling, constitutive modeling of fiber-reinforced concrete and implementation of rate effect. Although a strong theoretical background of the author is clear, for a reader not sufficiently strong in the presented topic, these sections may seem unnecessary brief lacking some important details. For example, it would not heard to provide more details in Section 3.4 on both the random field function and autocorrelation function. In addition, the presentation of the applied theory often reduces to the list of equations copied from literature without providing further details.
The core of the thesis I find in Chapters 6 and 9 presenting the results of extensive numerical simulations including numerous parametric studies suggesting some drawbacks of the present state of the art formulations provided mostly by Cusatis et al. Unfortunately, these are not further elaborated towards some improvements, so it is difficult to judge the authors own contribution apart from a noticeable programming effort. Explanation of the results would also deserve at some places more attention, see e.g. Section 9.6 which ends by stating that the specimens were loaded in tension and that the random field was considered. It is then up to reader to draw his/her own conclusion regarding the presented results.

Hodnocení:

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Význam disertační práce pro praxi a pro rozvoj vědního oboru

I suppose this is still an open question. While the discrete particle modeling approach may clearly identify the mechanisms driving the crack evolution through the material once exceeding the local strength limits, the computational burden and difficulty in tuning the material parameters of the constitutive models, which often, as suggested by the author, quite differ from those obtained experimentally, may provide an obstacle towards wide acceptance of this approach among practical engineers. But since I am not expert in this field, I promote the author to comment on that during the thesis defense.

Hodnocení:

☐ vynikající	☒ nadprůměrné	☐ průměrné	☐ podprůměrné	☐ slabé

Formální úprava disertační práce a její jazyková úroveň

The thesis is written in a relatively good English with no major flaws. Perhaps a point of criticism is linked to the use of articles, which are basically omitted particularly towards the end of the thesis. Graphical presentation of the results is well chosen and clear.

Hodnocení:

☐ vynikající	☒ nadprůměrná	☐ průměrná	☐ podprůměrná	☐ slabá

Hodnocení publikační a jiné činnosti doktoranda

I found the level of publication sufficient. Particularly in view of the potential presentation of the derived results, which certainly deserve attention.

Hodnocení:

☐ vynikající	☒ nadprůměrná	☐ průměrná	☐ podprůměrná	☐ slabá

Poznámky a připomínky k textu práce

1. The word heterogeneous could be perhaps clarified. In my opinion, the material is homogenous with the effective stiffness combining properties of grains and cementitious matrix. The source of heterogeneity then comes from application of fibers only. Obviously, the local fields might be nonhomogeneous and response might be locally anisotropic. Nevertheless, a random orientation of grains most probably results in macroscopic isotropy. Please make a comment on that.
2. The question of scale should also be perhaps clarify. When referring to mesoscale I would expect making distinction between the grains and mortar phases. Does the size distribution of polytopes somehow comes from the size distribution of grains in concrete? Then, unless considering fibers I do not see the difference with the scale of concrete. Next, should individual polytopes represent the actual grains I found the size of some specimens inadequate, e.g. the 60 mm specimen used in Chapter 6. In this section it would be perhaps better to refer to a cement paste. Can you please make a comment on that?
3. Individual sets of data used in different simulations are often slightly changed, which makes some comparison difficult. For example, the conclusions drawn from the results presented in Fig. 6.6 do not quite match those presented in Fig. 6.4. In Fig. 6.4 the results corresponding to half the original strength suggest more brittle response as oppose to the results presented in Fig. 6.6. Further to Fig. 6.4 the sentence on page 35 starting with "As expected, lower forces...." is not clear to me. The non-zero Gd generates almost the same peak load, but the post peak response is more ductile. Or am I missing something?
4. It appears that the mass stiffness matrix, Eq. (8.6), is assembled at Voronoi cell nodes whereas the stress-strain law in Chapter 3 is written for dofs associated with the Voronoi cell centroids. I must be missing something here. Please explain.
5. It is not clear to me, how the function F(\dot{w}) may affect the elastic branch of the failure envelope. If "w" stands for the crack opening the material must be loaded first beyond the elastic limit, so exceeding the initial failure envelope, for this function to become active. This is perhaps just a terminological issue. Please explain.
6. Question on numerical damping – the first sentence on page 82 is not clear to me. What exactly do you mean by "...it suffers from numerical damping"? It is known that standard trapezoidal rule with gamma=0.5 does not introduce numerical damping. As suggested, gamma must be greater than 0.5, which, however, reduces accuracy to first-order. So what is the difference between the integration schemes assumed for both methods and why the explicit method was used in the continuous model?

Závěr

Uchazeč zpracováním disertační práce prokázal způsobilost k samostatné tvůrčí vědecké práci ve smyslu § 47 zákona č. 111/1998 Sb. o vysokých školách a změnách a doplnění dalších zákonů.

Doporučuji, aby disertační práce **byla** přijata k obhajobě a aby v případě jejího úspěšného obhájení byl

Ing. Josefu Květoňovi

udělen akademický titul „doktor" (ve zkratce „Ph.D." uváděné za jménem).

Datum: 20.11.2019 Podpis oponenta práce: ..