20 sec

Today I’m going to talk about my research

About Simulation of Concrete cracking pattern

Combining

ASR and DEF expansion

20 sec

We will first go through background,

Then introduce our methodology and model,

Followed by simulation result on cracking pattern

And Mechanical Properties

Finally the conclusion

30 sec

ASR and DEF, are two common reasons of concrete expansion,

actually causing us a lot of troubles,

For example, the ASR damaged bridge reported in Hokuriku, Japan

(Click)

And sever DEF damaged concrete sleeper, in Indian.

These kind of expansion not only bring us aesthetic concerns,

But also damage the residual capacity

Finally become a safety issue.

50 sec

Though ASR and DEF both cause increasing in volume,

Their mechanisms are actually different.

(POINT AT EXPANDING INTERFACES)

Alkali silica reaction, introduce expansion by generate gel between mortar and ASR reactive aggregate,

Result in the volume increasing in whole structure

(Click)

While Delayed Ettringite formation happening in the paste, where mortar itself increase volume.

Their behaviors in meso scale actually pretty close,

Similar map cracking pattern can be formed.

(POINT AT CRACKS)

Their impact on Reduction of Mechanical properties are also different.

As experiments of ASR and DEF can take years, and the difficulties to analysis these two complicated phenomena quantitively,

Here we use simulation to

30 sec

Represent the ASR and DEF Expansion behavior,

Their reaction under Loading,

And their residual mechanical properties after expansion.

In this way we try to related the expansion behavior of structure directly to its mechanical properties losses,

Finally may helping evaluating structures damaged by expansion which are in using,

Predict their ability and duration of serving.

60sec

Here we tried to Simulate these two by RBSM, to represent their expanding behavior, and analysis their residual mechanical properties

For this object, Rigid Body Spring model is a good method.

it can model aggregate and paste elements separately,

And directly formulate the behavior of all elements during expansion.

In previous research, done by Eddy san

RBSM can successfully simulate single expansion case for ASR,

But its apply in DEF is not succeed.

So here we will improve the method for DEF,

And analysis on multiple cases under different conditions of ASR to get more systemized results.

50 sec

Here I’ll introduce how our simulation is working.

First, we build 3D model, add coarse aggregate at the amount we want, and mesh the whole structure into randomized elements.

And then, the expansion is applied,

For ASR, initial strain is given between ASR reactive aggregate and paste element,

While for DEF, initial strain is given between paste and paste element

Then, we go into the uni-axial compressing test,

0.02mm displacement here is applied step by step on the top surface with fixed boundary condition,

And the compressive strength at each step will be recorded.

30sec

In this page the ASR trail expansion using 10x10x10mm single aggregate model is presented.

As Initial Strain is given between aggregate and surrounding paste element, aggregate is under compressive condition during expanding.

With the distribution of inner stress, crack start to generate and deformation appeared.

Then we use the expanded model in loading simulation

In each step top boundary shift downward 0.002mm

Crack enlarged and finally it failed.

30 sec

Similar trail is carried out also for DEF, giving uniformed 0.0003 initial strain in paste per step.

As Initial Strain is given here is between paste elements, aggregate is under tension in the beginning of expansion. After surrounding elements detached with aggregate due to deformation, aggregate is not under stress anymore.

Uniform expansion can be seen in the expanded paste part.

And its behavior under fixed boundary loading is similar to ASR example.

50 sec

Ok. From here I’m showing our simulation result.

Firstly, ASR Expansion

Here, some different models are used, all of them size in 100 by 100 by 100 millimeter

But With different percentage of coarse aggregate and different percentage of ASR reactive coarse aggregate,

The expanded results can be different

(CLICK)

For example, if with 30% percent Aggregate, among them 25% are ASR reactive, the result would be like:

And if we increase the Reactive coarse aggregate to 75%,

It still shows the map cracking pattern, but become more compact

Similarity can be seen if we compare our simulation result with experimental results.

60 sec

By comparing them with the ASR cracks in reality, we can see that the characteristic map cracking pattern is well presented ,

Just the density of map patterns is different.

(CLICK)

If we look closer on distribution of cracked interfaces, with less Reactive Coarse aggregate, more cracks concentrated in relatively larger width range.

While for case with more reactive aggregate, both crack width and surface cracking shown is more well distributed.

70 sec

Next, we will go into the expansion of DEF

In previous study, simple uniformly paste expansion does not succeed,

Which means that we have to find another way around.

(CLICK)

In research of DEF expansion happens in Indian railway sleepers,

Anupum recorded the temperature of speciment during steam curing,

From his result, when the outer temperature is ideal,

The inner part temperature is significantly higher.

(CLICK)

As DEF is closely related to maximum curing temperature,

the inner part of structure should suffer more from DEF expansion

(Click)

So

Here we made model for

(point agg)

30% aggregate case

And set different range of DEF expansion intensified zone,

From 50 by 50 by 50mm inside to uniformly overall expansion, for comparing

15 sec

And here we can see,

While the uniformed overall expansion does not show crack

map cracking patterns are shown in all center intensified cases,

(point at 50, 75)

Similarity can be seen if we compare our simulation result with experimental results.

40 sec

Next, uni-axial compressive test is carried out on expanded models

Firstly, ASR

for model with 30% coarse aggregates, 75% of which are set to be ASR reactive

We can get the remain compressive strength comparing to non-damaged one

Of the cases expanded from 0% to 1.3%

The compressive strength is gradually decreasing as we increase the global expansion.

this result is also close to some of the experimental results.

15 sec

And for ASR reactive aggregate percentage,

If we choose 25% of them to be ASR reactive, not 75%,

Compressive strength generally decreases by 20%

30 sec

Similar loading test is also done on DEF expanded models

with 50x50x50 inside zone giving intensified DEF expansion,

(click)

We can also see the decreasing trend of compressive strength when we introduce larger expansion,

Which is also close to some of the experimental results

20sec

However, though changing the inner zone where expansion intensified significant changed the cracking behavior,

It does not have large impact on the compressive strength.

The residual compressive strength in all three series of cases are very close.

80 sec

By cross comparing the simulation result of ASR and DEF

We can see that there are many differences among them,

Such as inner stress distribution

Crack distribution

And the residual mechanical properties are not change in the same ratio with changing of global expansion.

Does this mean there is no commonly used relationship between their expansion behavior and residual mechanical properties?

Nope.

General relationships are found between the number of cracked interfaces which larger than 0.01mm and the residual compressive strength.

With greater number of large cracks, for here we used 0.01mm, the residual compressive strength almost linearly decreased, in all ASR and DEF cases.

Which implies that the residual compressive strength may not determine by global expansion ratio, but the large cracks generated during the expanding procedure.

80sec

In conclusion, our simulation by RBSM is a suitable choice for ASR and DEF expansion.

In both ASR and DEF case, characteristic map cracking pattern is represented

Damage in compressive strength is simulated and close to some of the experimental results.

By comparing between expensed cases with different mechanism, we can see the residual mechanical properties also changed significantly

Finally, the relationship between Residual Compressive strength and number of wider cracked interface are confirmed. In same global expansion ratio, with more concentrated crack, loss in mechanical property will be much severe.

And hope this research could help the non-destructive evaluation of ASR and DEF damaged concrete structure, predict their residual capability of serving.