Uniformity Evaluation of Self Compacting Concrete Properties in Beam-Column Structural Elements Using Non-Destructive Testing

by Nyoman Kencana

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Abstract

Self-compacting concrete (SCC) is a new type of concrete which can easily flow and consolidate without any compaction due to the present of high content of water reducing while keeping a low water-cement ratio. There are many advantages using SCC during construction practice; for instance reducing cost and maintaining the good working environment. Therefore, use of SCC has been increased since it was introduced in 1980's. However, segregation and settlement have to be concerned in such congested section or complicated reinforcement like in beam-column structural elements. The uniformity of the properties of SCC in this element was investigated using non-destructive testing (NDT)-hammer testin some considering point of elements in this research. The specimens are full-scale of beam-column structural elements. It consists of three specimens made from SCC and three specimens made from conventional concrete as comparison (NC). To confirm the result of hammer test, the specimens were then loaded until failure. According the hammer test, there is only slight differences in rebound number between NC and those of SCC indicatingthere is a uniformity of structural elements. However, during structural testing, in higher reinforcement ratio, the SCC aren't able to reach the maximum load as NC due to early failure occurred in column indicating there was a problem during placement which cannot be detected during NDT. More than one NDT tool has to be utilized to evaluate the uniformity of structural elements.

Keywords: Self Compacting Concrete, Non-destructive Testing, Hammer testing, Beam-column, Properties Uniformity

1. Introduction

Self-compacting concrete is a type of concrete which doesn't need vibration during placing due to high flow ability properties. The ability of self-levelling nature of SCC offers many advantages; for instances enhancing construction properties, reducing overall cost, improving working environment (Zhu, 2001). Therefore, the use of SCC in construction practice has been increasingly since it was invented in the early of 1990s in Japan.

However, the hardened properties of SCC, that are very important in structural design have only been analysed solely to mechanical properties such as compressive strength and modulus elasticity. In fact, since SCC has the ability of self-compacting, inadequate homogeneity of hardened SCC due to either segregation or poor compaction need to be considered.

To ensure the uniformity distribution of SCC in a structure mainly in congestion place due to heavy reinforcement has still to be reviewed. Therefore, this research is aimed to investigate the homogeneity of SCC in full scale beam-column structure using non-destructive testing.

2. Related Works and Theory

An experimental and numerical research on mechanical properties, such as strength, elastic modulus, creep and shrinkage, of self-compacting concrete (SCC) and then the results were compared to the corresponding properties of normal compacting concrete (NC) has been investigated by Persson, (2001) and Domone (2007). It was observed that the properties on elastic modulus, creep and shrinkage of SCC were almost similar to the corresponding properties of NC.

Zhu et al., (2001), has studied on uniformity of in situ properties of SCC mixes in practical structural columns and beams. The properties were compared to those of well compacted conventional concrete (NC). The properties were investigated using testing cores, pull-out of pre-embedded inserts, and rebound hammer number for near-surface properties. The research found that there were not significant differences in uniformity of in situ properties between SCC and NC.

2. 1. Self-Compacting Concrete (SCC)

SCC is a modern concrete that does not need vibration duringplacement and compaction. It can flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is able to be dense, homogeneous and has similarmechanical properties and durability toconventional vibrated concrete. SCC is usually produced with low water-cement ratio which can achieve high early strength, earlier de-moulding and faster use of elements and structures.

According to The European Standar for Self-Compacting Concrete, (2005), to examine the fresh properties of SCC, some testing should be conducted. Slump-flow value describes the flow ability of a fresh mix in unconfined conditions. It is a sensitive test that will normally be specified for all SCC, as the primary check that the fresh concrete consistence meets the specification. Passing ability describes the capacity of the fresh mix to flow through confined spaces and narrow openings such as areas of congested reinforcement without segregation, loss of uniformity or causing blocking.

Superplasticisers or high range water reducing chemical admixtures is the primary component of SCC. This admixture achieves the required water reduction and fluidity as well as maintains its dispersing effect during the time required for transport and application.

2. 2. Non-Destructive Testing (NDT)

It is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete. Non-destructive testing can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy.

One of the well-known NDT on concrete structures is The Schmidt rebound hammer. Hammer test is principally a surface hardness tester. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges (Malhotra and Carino, 2004)

3. Experiment

3. 1. Materials and Mix Designs

Concrete aggregate consists of coarse aggregate made by crushed stone which has maximum diameter of 20 mm and fine aggregate which has 5 mm in maximum diameter. The specific gravity of of fine and coarse aggregate were 2.56 and 2.69 respectively. The grading curves of coarse and fine aggregate are illustrated in Figure 1. Cement type was Portland Cement Type 1. The water cement ratio is kept by 44% for whole mixture of SC and SCC. The flow ability was provided by high water reducing admixture, a brand from Sika, named Sika Viscocrete. The mixture proportion of SCC and NC is shown in Table 1.

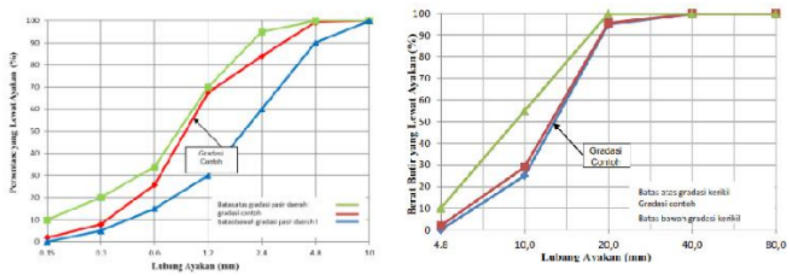


Figure 1. The grading curves of coarse and fine aggregate

Table 1. Concrete mixture proportion

Concrete Type	Mixture Proportion (kg/m^3)				
	Water	Cement	Fine Aggregate	Coarse Aggregate	Superplastisizer
NC	225	510	922	668	-
SCC	200	450	790	962	0.8% of cement weight

To check the properties of fresh concrete, some test were conducted both in SCC and NC to describe whether the mixture meet the specifications. The fresh properties of concrete are shown in Table 2.

Table 2. Fresh properties of concrete

Fresh Properties	NC	SCC	Required Value
Slump (cm)	13	-	7.5-15
Slump Flow Spread (cm)		68.2	65-80
J Ring Test (cm)		63.5	60-85

A set of three concrete cylinders of NC and SCC were prepared to examine the compressive strength. The sizes of cylinders were150 mm in diameter and 300 mm in height. Full scale beam-column structural elements of NC and SCC were casting according to mix design shown in Table 1. The detail of dimension and bar arrangement of full scale beam-column is shown in Figure 2. The steel reinforcement (Figure 2) were design in two ratio which were low and high reinforcement ratio to provide such an adequate spacing and constricted spacing respectively in concrete. All the materials and test procedures was based on Indonesian Standard.

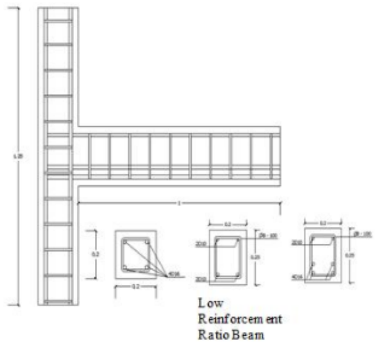
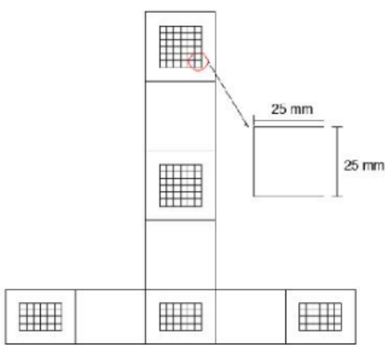


Figure 2. Beam column specimen and detail of reinforcement

3. 2. Methods

Testing was carried out at the age of 28 days of specimens. After rebound numbers reading were conducted, the destructive testing was applied on both cylinder concretes and structural elements. To prevent sway during hammering, the cylinder concrete was braced using compression testing machine. At least ten readings were taken in each location as shown in Figure 3.The beam column elements were loaded by static flexure load at beam end until failure. The setting up of structural testing is shown in Figure 4.



Hammer Testing Location on Beam-column

Hammer Testing on Cylinder

Figure 3. Hammering location on beam-column and cylinder specimen

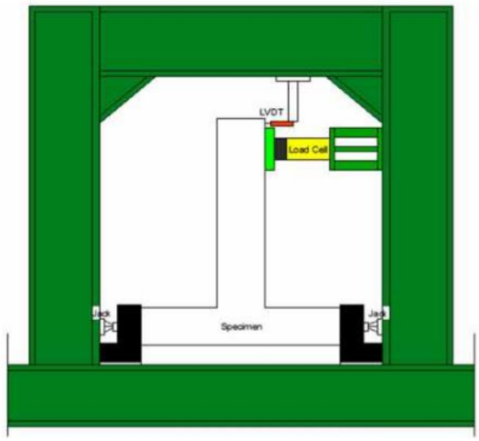


Figure 4. Beam-column testing set-up

4. Results and Discussion

4. 1. Concrete Cylinder Compressive Strength and Rebound Number

With the same target strength during mixture proportion design, NC has greater compressive strength and rebound number than those of SCC as shown in Table 3. During mix design, NC has greater cement content than SCC causes NC has greater compressive strength than those of SCC. Greater strength leads to produce higher rebound number during hammer test.

Table 3. Compressive strength and average of rebound number

Concrete Type	Compressive Strength(MPa)	Average of Rebound Number
NC1	38.4	30.7
NC2	39.0	30.6
NC3	38.7	30.7
Average	**38.7**	**30.6**
SCC1	31.0	29.2
SCC2	30.7	28.7
SCC3	30.1	29.7
Average	**30.6**	**29.2**

4. 2. Hammer Test on Beam-Column Structural Elements

There is only slight differences in rebound number between NC and those of SCC as shown in Figure 5. Moreover, in joint, SCC shows slight better rebound number, indicating that SCC has good placement performance even in such congestion places. According to the result of hammer test, there are no significant differences in uniformity on structures between SCC and NC.Homogeneity is found in SCC, since the different of RN in each hammering location are found not more than 5 (ASTM C805, 2013).

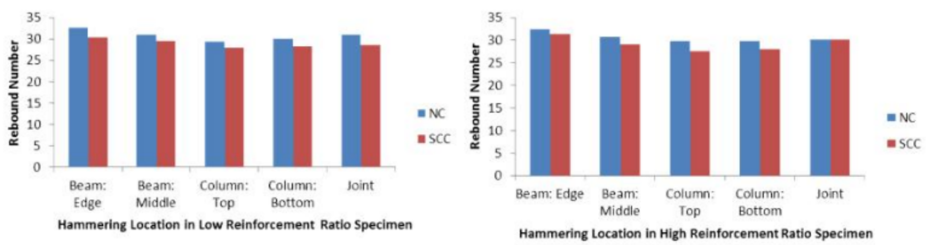


Figure 5. Rebound number in each location of beam column specimens

4. 3. NDT Result Confirmation Using Structural Testing

Maximum load of NC and SCC in lower reinforcement ratio are almost similar as shown in Table 4. It only differs 10% indicating there is uniformity present in SCC as expected similar to that in NC. However, according to the relationship load-displacement obtained from structural testing as shown in Figure 6, even both concrete have almost similar maximum load, but in the early of load level, NC shows more stiff that that of SCC. This is common due to greater compressive strength of NC.

Table 4. Maximum load

Reinforcement Ratio Type	Maximum Load (kN)		Maximum Load SCC/NC (kN)
	NC	SCC	
Low ratio	23.3	20.9	0.90
High Ratio	42.8	28.3	0.66

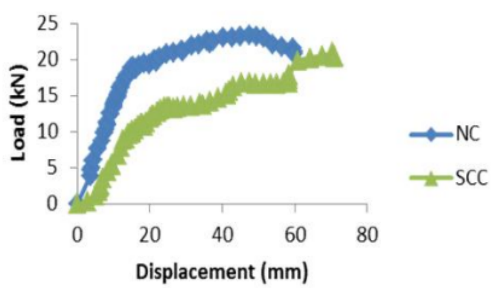


Figure 6. Load-displacement relationship of lower reinforcement ratio

Furthermore, in higher reinforcement ratio SCC only reaches 66% load of NC maximum load. SCC beam-column aren't able to reach the maximum load as NC due to early failure occurred in column. Early failure in column indicating there was a problem during placement due to non-homogeneity such as voids or honey combing. This performance has the opposite result to the rebound number. This problem isn't able to be detected by hammer test which only can evaluate surface hardness. Therefore, more than one NDT should be used to check the uniformity of SCC because hammer test is only able to detect the condition of material surface.

5. Conclusion

This research investigate the investigate the homogeneity of SCC in full scale beam-column structure using non-destructive testing (hammer test). According to NDT, there are no significant differences in uniformity on structures between SCC and NC. During structural testing, maximum load of NC and SCC in lower reinforcement ratio are almost similar, indicating good placement of SCC. In higher reinforcement ratio the SCC aren't able to reach the maximum load as NC due to early failure occurred in column showing non-homogeneity occurred in column which is not detected by hammer test, which only enables to detect the surface hardness.

Acknowledgement

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