CHAPTER II

LITERATURE REVIEW

Reinforced concrete is one of the most common construction materials for building. According to Hardjasaputra et al. (2011) concrete construction in Indonesia was introduced by Prof. Rooseno and the development of concrete construction in Indonesia have reach the produce of concrete with a strength of 70 Mpa. But these days the world has discovered a new generation of concrete known as Ultra High-Performance Fiber Reinforced Concrete (UHPFRC). UHPFRC have greater strength and ductility than other type of concrete. High strength and ductility mean taller member, smaller cross section, and more space. Because of this benefit the use of UHPFRC is suitable for heavy loaded structural component, in this case the column.

UHPFRC is a specially formulated concrete with a compressive strength of more than 120 Mpa that have steel fiber content of 2% or more. The development of UHPFRC started in 1994 by Richard et al. in the form of reactive powder concrete. RPC was characterized by high binder content, very low water-to-cement ratio (w/c), use of silica fume, fine quartz powder and superplasticizer and fibers. It has compressive strengths ranging from 200 to 800MPa. UHPFRC behavior in compression is almost the same as regular concrete. The different between UHPFRC and other concrete can be seen in its tensile behavior. UHPFRC have a relatively large tensile strength, the tensile strength of UHPFRC rage from 15 to 150 Mpa and flexural strength of 30 to 141 Mpa depend on the composition, casting, and curing condition(Wang et al, 2015). In tensile UHPFRC after the first crack the UHPFRC will perform strain hardening because of steel fiber that resist tensile load, and after peak stress it will perform some strain softening. Figure 2.1 and Figure 2.2 shows the usual UHPFRC under compression and Tension.

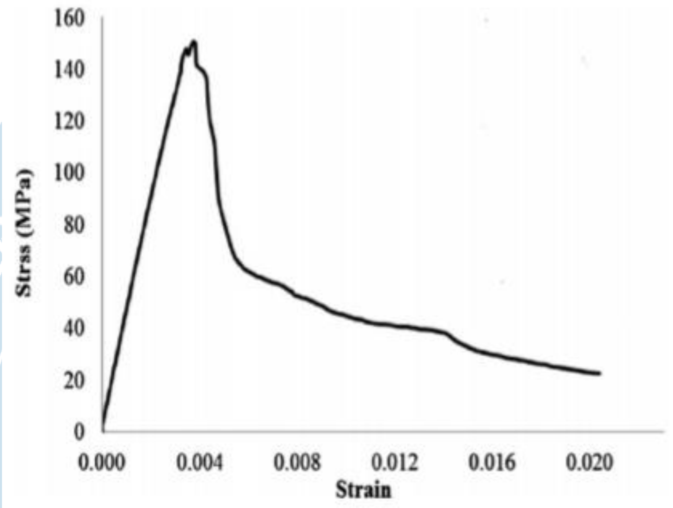


Figure 2.1 UHPFRC Stress-Strain Graph Under Compression (Shaikh et al, 2020)

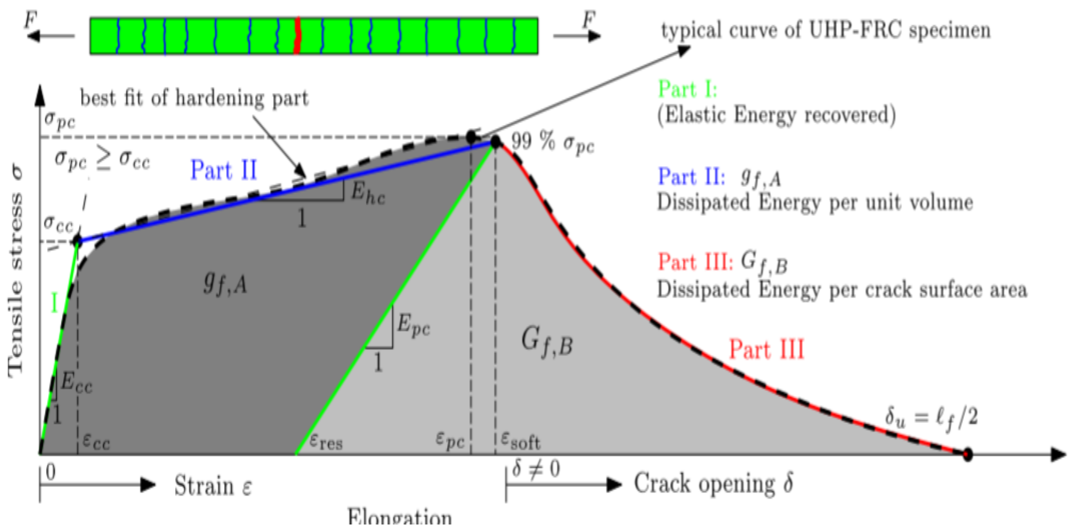


Figure 2.2 UHPFRC Stress-Strain Graph Under Tension (Wille et al, 2014)

When properly reinforced with steel fiber, UHPFRC have high strength, superior ductility, provide exceptional energy absorption, and undergo distributed cracking with extremely small crack widths prior to crack localization. Tough UHPFRC possesses amazing properties it is fabrication is complicated and generally costly that makes it hard to replace the conventional concrete economically. Due to this problem there is a need to conduct a study regarding the behavior of UHPFRC in construction member before using it in real construction, in this case in column under axial load. The study of the effect of sand content on sand reinforcement interaction behavior can be done by doing a compressive test.

Heshe and Nielsen (1992) studied the pure axial behaviour of twenty-four small-scale UHPFRC columns having rectangular cross-section of 130 mm 158 mm. The test variables in this study included transverse reinforcement spacing and amount of longitudinal steel reinforcement. The authors of this study concluded that although confinement influences axial capacity in UHPFRC columns, the enhancement in ductility is more considerable. In addition, the authors mentioned that the direction of concrete placement has a noticeable effect on the capacity due the influence of fiber orientation, with the capacity being higher when concreting is parallel to the loading axis.

Sugano et al (2007) conduct an experimental on nine UHPFRC columns having square section of 200 mm x 200 mm under pure axial loading. It is noted that the columns in this study were reinforced with high strength transverse steel ties. The variables in this study included concrete strength (f 0 c = 120, 160, 200 MPa), fiber content (vf = 0% or 2%) as well as strength (f y = 700 MPa and 1400 MPa) and spacing of transverse reinforcement (s = 35, 45, 55 mm). from this case the author observed that in the column with no fiber reinforcement have a very small enhancement. On the other hand, columns with fiber reinforcement give different result. The result showing rise in compressive strength and ductility as the amount or strength of the transverse reinforcement increased. From Figure 2.1 shows how the peak strength of the column can surpass the concrete cylinder strength due to the confinement of transverse reinforcement (the concrete cylinder strength was symbolized with an X marks in the figure). In addition to the axial tests, the behaviour of UHPFRC under simulated earthquake loading was studied by testing six companion columns under reversed-cyclic loads; the results showed that an increase in confinement and provision of fibers improved the ductility of the columns under lateral loads.

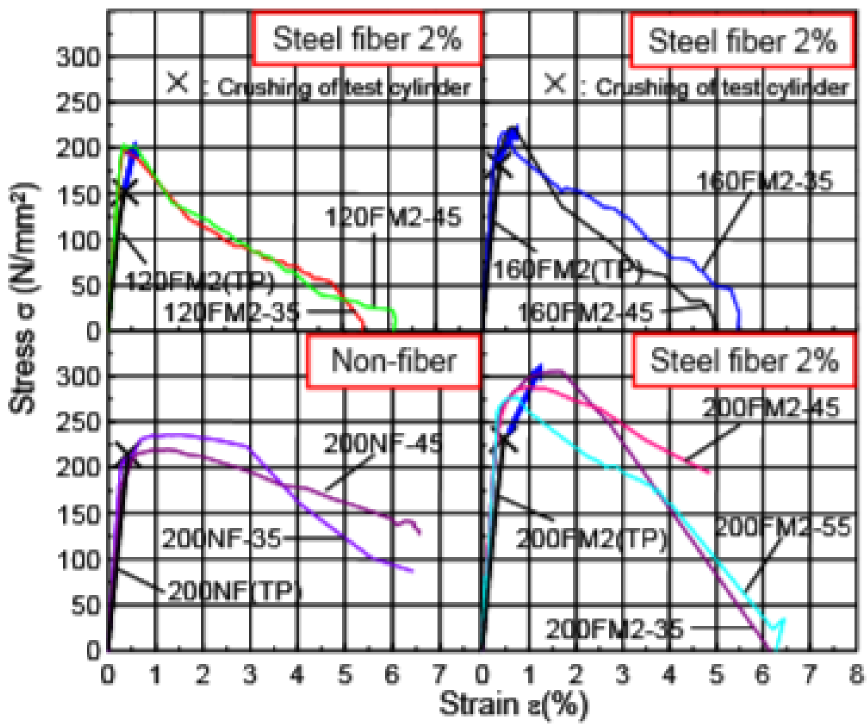
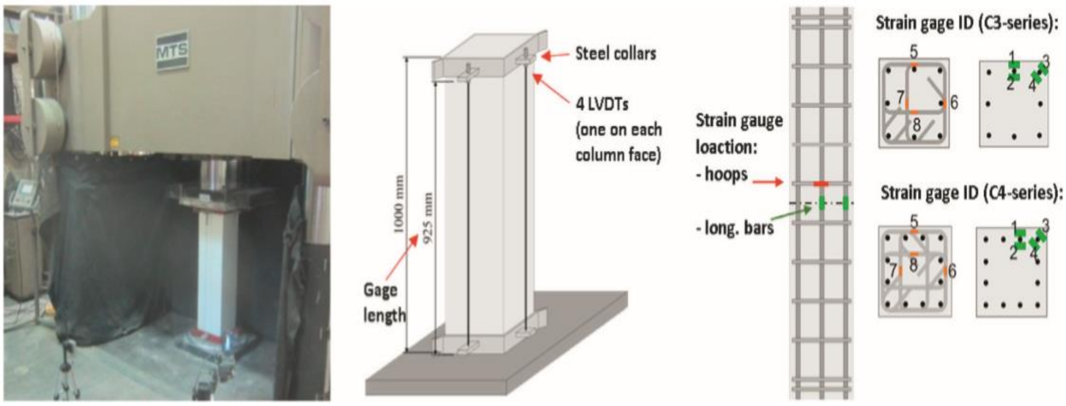


Figure 2.3 Result of Column Compressive Test (Sugano et al., 2007)

Hosinieh et al. (2015) conducted an experimental on six large scale of UHPFRC column under axial loading to examine the effect of UHPFRC and transverse reinforcement detailing on column performance. The columns have square cross section of 250 mm x 250 mm and 1000 mm in height with 2.5% fiber content. The variable in this study include number of longitudinal reinforcement bar (8, 12), transverse reinforcement (3 legs, 4 legs), tie spacing (s= 40,60,80,120 mm). Figure 2.2 show the Load-strain result of the six UHPFRC columns. For this case, the result show that the increased and well detailed transverse reinforcement can improves the confinement and ductility of UHPFRC columns. The configuration of the transverse reinforcement does not have a significant effect on column axial strength, although toughness improves. The effect on the post-peak strength decay is more significant in highly confined columns shown in Figure 2.3b, whereas only the toughness improves in the case of nominally confined columns due to the effect of bar buckling on the response of UHPFRC columns having large tie spacing.



(a) Column ready for testing (b) LVDT setup (c) Strain gage instrumentation

Figure 2.4 Column Instrumental and Test Setup for Compression

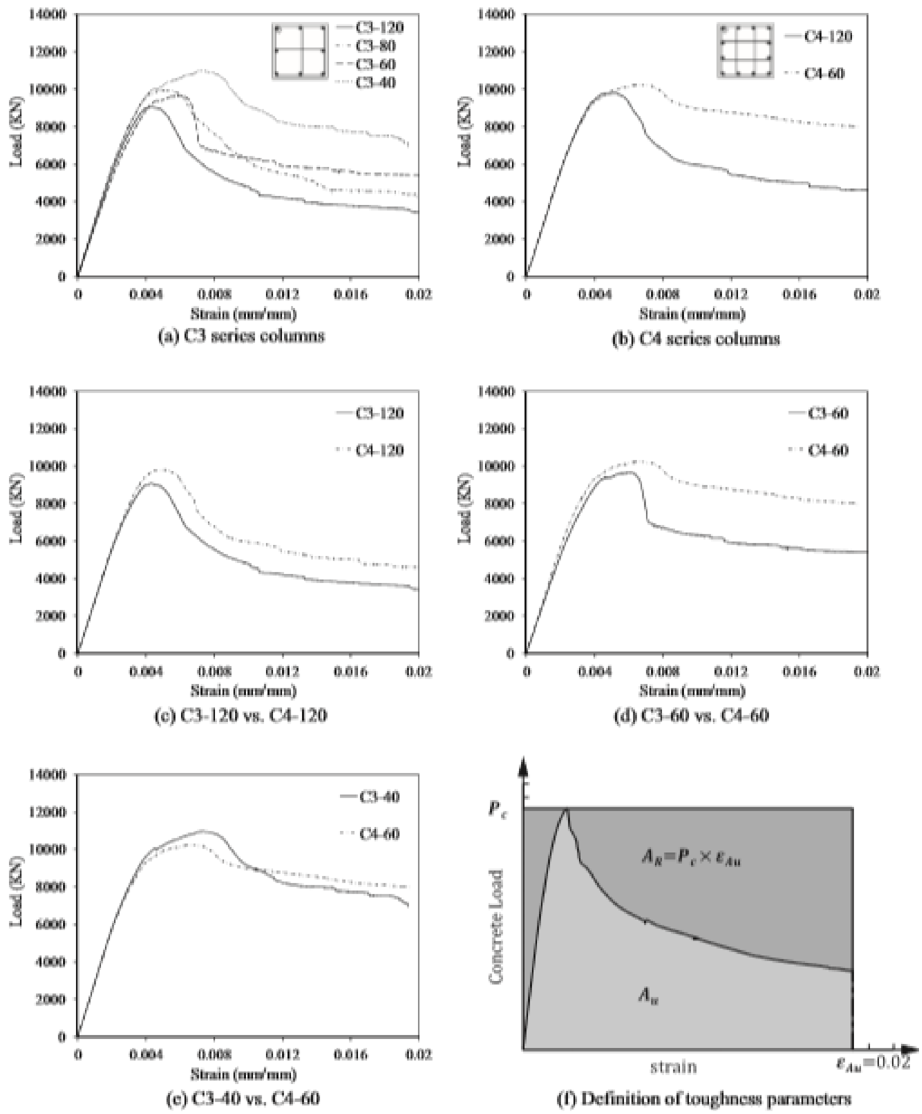


Figure 2.5 Load-Strain Result of UHPFRC Columns (Hosinieh et al., 2015)

Wang et al. (2016) has done some numerical study on the performance of UHPC bridge pier. This study uses finite element model (FEM) in its numerical study. The FEM that the author use is the fiber element model. Fiber elements can represent more accurately important aspects of structural response including the interaction of axial load and biaxial bending moment, confinement effect, and material softening behaviour. As a result, the nonlinear seismic performance of RC members is popularly researched with fiber elements derived from divided sections integrated by concrete and reinforcing steel fibers. This study FEM model is based on the OpenSees platform. The author use concrete02 and reinforcing steel material model provided by OpenSees model. The result shows that using fiber elements which was established based on OpenSees platform, can provide the bridge pier hysteretic response consistent with experimental data. Wang et al. (2019) done a numerical study on the behavior of precast UHPC bridge column. the study use the same parameter as wang et al, (2016) but for the concrete model he use concrete01. The result indicate that the model of UHPC Bridge column proposed analysis model was validated with good accuracy to predict the lateral skeleton curve, lateral stiffness, and opening at the base joint with less than 10% discrepancy.

Wong (2018) has done some numerical study in the Engineered Cementitious Composite (ECC) column under axial compression. The column has square cross section of 100 mm x 100 mm, 300 mm height, and compressive cylinder strength of 74.1 Mpa. Each column has a different variable of transverse steel confinement of 0%, 1%, 1,5% and 2%. The percentage of confinement is based on the tie spacing of the transverse reinforcement, respectively the spacings are 60 mm, 40 mm, and 30 mm. Finite element model was based on the OpenSees platform using NonlinearBeamColumn elements and fiber-sections. The author uses the concrete02 model provided by OpenSees rather than the ECC01 model, considering the material is ECC. Concrete02 was used because the compressive behaviour of concrete02 model can represent the response of confined ECC in compression. On the other hand, the ECC01 model have better performance then concrete02 when subjected to tensile. The result shows that the OpenSees analytical result show a reasonable response in comparison with the experimental result.

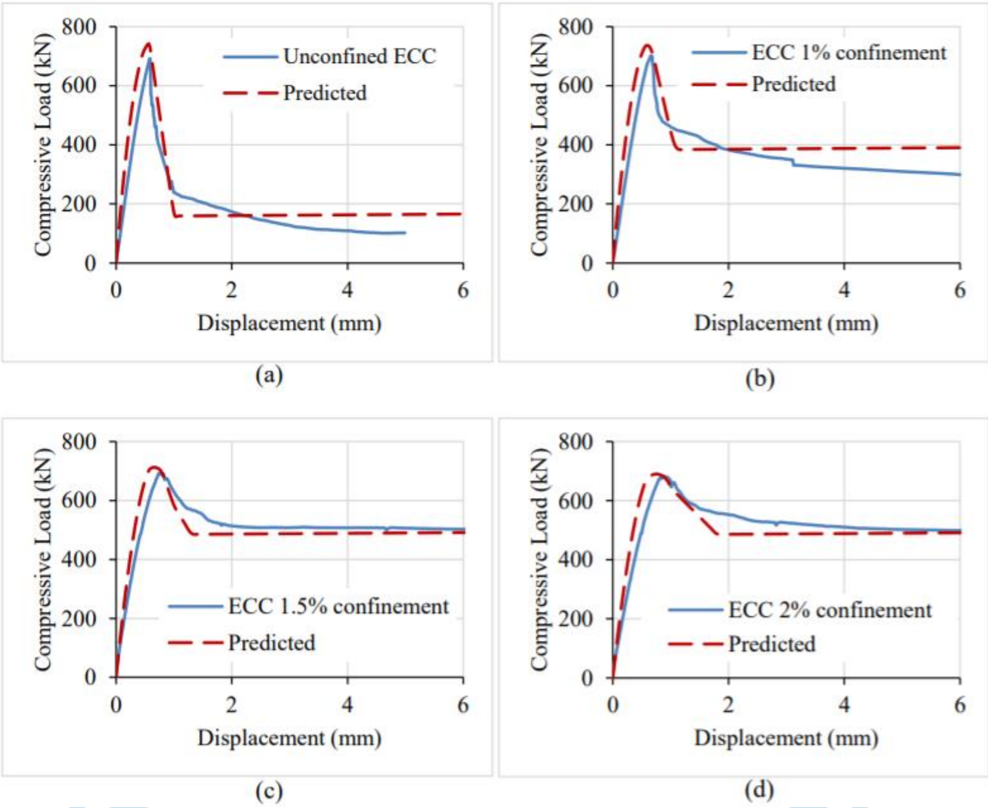


Figure 2.6 Load-Displacement Result of ECC columns (Wong, 2018)