Wang et al. 2019).

During construction procedure of CFST bridge, concrete pouring of the main arch structure is a key process. Method of concrete-pumping and lifting-up is the most widely used technology in CFST construction. While preparing self-compacting concrete (SCC) is the key to adopting concrete-pumping and lifting-up technology successfully. The combining degree between the core concrete and steel tube affects not only the construction quality but also the safety and stability of the whole bridge(Ma, Wang et al. 2016; Xie, Wang et al. 2019). To ensure the compactness of the filling concrete in the steel tube and good ferrule effect between the steel tube and the confined concrete, micro-expansive SCC has been the optimum selection(Yang, Cai et al. 2015; Ma, Wang et al. 2016).

For SCC, high fluidity, good segregation resistance and gap passing performance are all required to ensure the homogeneity of the mixture in the transportation and pouring process, and to be able to fill mold compaction by self-gravity. Natural sand (NS) is mostly used as fine aggregate for traditional SCC. But due to shortage of natural sand resources and inconvenience of transportation in some special areas, such as mountainous areas in the western part of China, manufactured sand (MS) has become the inevitable alternatives to prepare SCC. Comparing with NS, the particles of MS not only have rough surfaces but also are much more angular. Moreover, high content of stone dust is another important difference between MS and NS (Li, Zhou et al. 2011; Bo 2016).

Lots of experimental researches have been carried out to investigate effect of stone dust on the performance of MS-SCC(Bosiljkov 2003; Gui, Zeng et al. 2011; Li, Zhou et al. 2011; Bo 2016; Xiaofang, Jun et al. 2016). Researches of (Gui, Zeng et al. 2011) indicated that Methylene blue (MB) and stone dust content of MS were important indexes for the workability of MS-SCC. For the situation MB less than 1, stone dust with no more than 15% content will help to improve workability of MS-SCC; for the situation MB greater than or equal to 1, the workability off SCC was sensitive to the change of stone dust content and the content must be less than 5%. To meet the requirements of construction of CFST arches, a C60 grade micro-expansive MS-SCC was prepared in (Li, Zhou et al. 2011). The workability, compressive and splitting strength, modulus of elasticity, restrained expansion and chloride ion permeability as well as freeze-thaw resistance of three MS-SCC mixes with fines content of 3%, 7% and 10% were tested and compared with those of the NS-SCC mix. Results show that the performances of the C60 MS-SCC with fines content of 7% are excellent and compared favorably with those of C60 NS-SCC. In (Xiaofang, Jun et al. 2016),C50 SCC was prepared with MS from limestone in Guizhou Province, China. Similar conclusions were also obtained, such as appropriate stone powder content would improve working performance and increasing compressive strength of SCC. Meanwhile, experimental results also demonstrate that the increase of stone powder content can slightly reduce the concrete's dynamic modulus, chloride penetration resistance, carbonization resistance and sulfate erosion resistance, and has no obvious effect on concrete shrinkage. Experiments in (Benyamina, Menadi et al. 2019) demonstrate that increasing the substitution level of limestone fines in SCC mixtures, contributes to the decrease of the slump flow and the yield stress. Moreover, the inclusion of limestone fines as crushed sand substitution reduces the capillary water absorption, chloride-ion migration and consequently enhances the durability performance. According to the above, the feasibility of preparing high-performance strength MS-SCC with certain stone powder content, including high strength, has been fully demonstrated.

In fact, the performance of MS-SCC depends on the properties of the raw materials a lot. MS-SCC prepared with different kinds of raw material has been investigated to acquire higher strength and application in different projects. Ding (Qingjun, Yi et al. 2017) prepared C100 CFST with high stone powder MS, low air content, ultra-dispersion polycarboxylate superplasticizer and fly ash beads+silica fume. The research results are applied with satisfactory to the construction of concrete filled steel tubular arch rib of Guan Sheng River Bridge in Sichuan, Guang'an. Kumar (Kumar and Radhakrishna 2016) investigated the characteristics of SCC with fly ash and MS through experiments. SCC of M40 grade was designed. The binder in SCC consists of OPC and fly ash in the ratio of 65:35. NS was replaced by MS at replacement levels of 20,40,60,80 and 100%. For each replacement level, constant workability was maintained by varying the dosage of superplasticizer. Zhu (Zhu, Cui et al. 2016) carried out experimental investigation of the effect of MS and lightweight sand (LS) on the properties of fresh and hardened self-compacting lightweight concrete (SCLC). Test results show that increasing the sand ratio (from 0.40–0.50) decreased the filling ability and led to an increased T50 time, the passing ability of MS-SCLCs and LS-SCLCs is still within an acceptable range.

In this paper, aiming to the application of MS-SCC in Zongxi River Bridge, using the local MS in Guizhou province, 11 groups of self-compacting concrete ratios were designed. Influences of concrete admixture, mechanical sand powder content, aggregate volume and expansive agent on the mechanical properties and working performance of concrete were studied. To further demonstrate the practical workability, an in-site concrete filling simulation test with 1:1 ratio was carried out.

2. ENGINEERING BACKGROUND

2.1 Bridge Overview

Zongxi River bridge, an oversize CFST deck truss arch bridge, is the key project of Bijie-Duge expressway in Guizhou Province, China (Xin-hua, Shao-hui et al. 2016). With main span of 360 m, the bridge crosses over a V-shaped valley, shown as in Fig.1. The main arch is catenary shape with arch axis coefficient m = 1.3, vector height h = 69m and vector span ratio f = 1/5.217. To fill concrete into the steel tube compactedly, C55 self-compacted micro-expansion concrete is adopted. However, the distance from the bridge to the nearest provincial highway is 7 km, and there is only one village road on each bank side of the bridge. In such poor transportation conditions, prepare C55 SCC with local MS is the most appropriate choice.

A space truss structure with constant width and variable height is adopted for the main arch, and the section height varies from 6m at the arch top to 12m at the arch foot (middle to middle). The main arch chord is CFST section, including 4 upper chord pipes and 4 lower chord pipes. The upper and lower chords are horizontally parallel with each other, and the transverse center distance is 4m (both sides) and 10m (middle).

According to the stress situation, the upper and lower chords are made of variable-section steel pipes. The size of the upper chord steel tube changes from Φ1200 mm×26mm at the arch foot to Φ1200mm×35 mm at the arch top, while that of the lower chord changes from Φ1200 mm×35mm to Φ1200mm×26mm. According to the need of strength and stability, there are also bracings designed to connect and stiffen the arch tubes, shown as in Fig.2. The butt-joint of steel tube arch rib is bolted with inner flange and welded outside. To solve the stress problems caused by debonding of concrete-filled steel tubular with arch ribs, Φ22mm×100mm headed studs are set on the inner wall of steel tubes at the joints of arch ribs. The studs can not only strengthen the bonding effect between steel tubes and core concrete, but also assist the transferring of shear force on the arch rib cross section. See Fig.3 for the arrangement of headed studs in chord tubes.

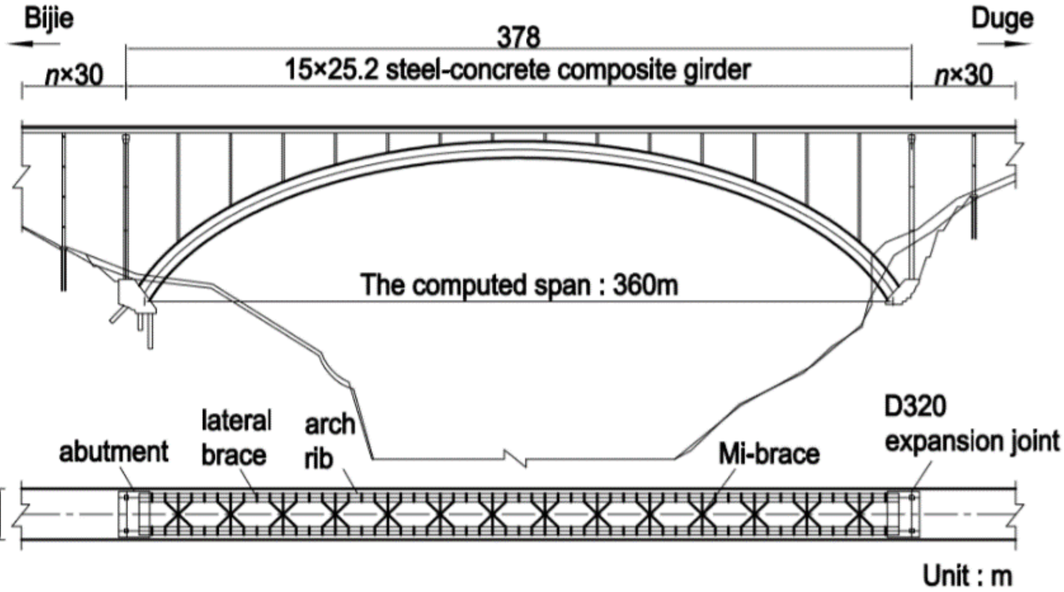
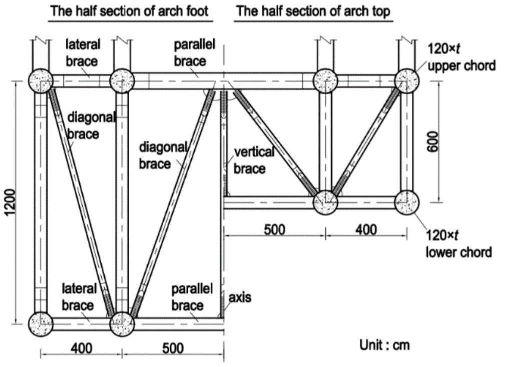


Fig.1 Overall layout of Zongxi River bridge



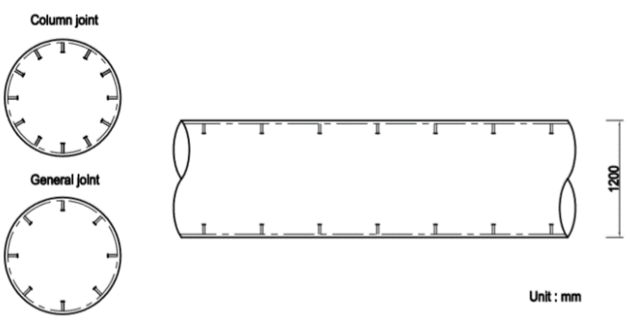


Fig.2 Sections of Main Arch

Fig.3 Studs Arrangement in Chord Tube Joints