# CF60 Concrete Composition Design and Application on Fudiankou Xijiang Super Large Bridge

Yi Mei QIU [1, a], Sen Yuan WEN [2,b] and Jun Xiang CHEN [3,c]

[1]Guangxi Vocational and Technical College of communications, Nanning, China
[2]Guangxi road & bridge engineering group co., LTD, Nanning, China
[3]Guangxi Transportation Research & Consulting co., LTD, Nanning, China

**Abstract:** Guangxi Wuzhou City Ring Road Fudiankou Xijiang super large bridge CF60 concrete is a new multi-phase composite high-performance concrete, this paper for the Fudiankou Xijiang bridge structure and characteristics of the project, in accordance with the principle of local materials and technical specification requirements, combined with the site conditions of CF60 engineering high performance concrete component materials, proportion and the technical performance, quantify the main physical and mechanical performance index. Analysis main influencing factors of the technical indicators, reasonable adjustment of concrete mix design parameters, and the use of technical means of admixture and multi-function composite admixture of concrete, obtain the optimal proportion of good work, process, mechanical properties stability and durability of engineering properties, recommend and verification of concrete mix; to explore the CF60 high performance concrete Soil in the Fudiankou Xijiang bridge application technology, detection and tracking the quality of concrete construction, concrete structure during the construction of the key technology and control points is proposed, evaluation of CF60 high performance concrete in the actual engineering application effect and benefit to ensure engineering quality of bridge structure and service life, and super long span bridge engineering construction to provide basis and reference.

## 1 Introduction

Guangxi wuzhou of ring road Fudiankou Xijiang super large bridge is from 1 # main bridge [145 m + 270 m + 145 m of short tower cable-stayed bridge] + 2 # main bridge [131 m + 198 m + 131 m continuous rigid frame bridge] + approach bridge [11 × 40 m first simply supported then the continuous T girder bridge], total length of 1474 m bridge. The integral deck a total width of 28.5 meters, cantilever construction is used super wide and multiple trusses hanging basket, the largest cantilever segmental weight of 667 tons, wide and segment of hanging basket are domestic rare. This bridge uses CF60 high performance concrete, which is a new multi-phase composite high-quality concrete, is made of high-strength concrete, high-flow concrete is optimized, requires a good workability, process, mechanics, stability and durability and other engineering properties, the quality of its design and casting quality is particularly important. This paper will focus elaborate CF60 high performance concrete mix optimization design and application technology.

## 2 CF60 concrete raw materials optimization

Fudiankou Xijiang super large bridge CF60 high performance concrete compared with ordinary concrete, it has more raw material variety, its uniformity, compactability to good , technical performance has improved significantly. Experience has shown that the most important to obtain high performance concrete technology is using the appropriate admixture and multifunctional composite admixture.

CF60 concrete according to the principle of local materials and the requirements of technical specification, for a variety of raw materials, such as cement, coarse aggregate, fine aggregate, water, admixtures and admixtures etc., physical, chemical and mechanical properties of the test, thus reasonable choice.

### 2.1. Cement

Cement as concrete cementation material, direct impact on the key technical performance of concrete structures. Through contrast test, CF60 concrete using in Guangxi Huayun (Pingnan) company limited P.II52.5 silicate

*Corresponding author: Email: [a]gx5635604@sina.com, [b]jychxb@sina.com, [c]chenjunxiangde@126.com

cement, quality is stable, the intensity fluctuation is small. Its main physical, chemical and mechanical properties of technical indicators test results as shown in table 1 and table 2.

## 2.2. Coarse aggregate

Coarse aggregate using Shiqiao Ma An Shan stone field (5-10) mm, (10-15) mm, (15-25) mm mixed macadam, Blending proportion:(5-10)mm:(10-15)mm:(15-25)mm=10%:30%:60%.Physical and mechanical properties of its main technical indicators test results such as listed in table 3 and table 4.

**Table 1** P. II52.5 physical and mechanical properties of cement

| Strength grade | Density ($kg/m^3$) | Specific surface area ($m^3/kg$) | Normal cosistency (%) | Stability C-A value (mm) | Condensation Time (min) | | Compressive strength (MPa) | | Bending strength (Mpa) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Initial | Final | 3d | 28d | 3d | 28d |
| 52.5 | 3160 | 373 | 26.70 | 2.0 | 154 | 207 | 32.3 | 60.3 | 6.0 | 9.0 |
| Conclusion | The are all items conform to "General Portland Cement " GB175-2007 strength grade standard P.II 52.5 of the technical requirements. | | | | | | | | | |

**Table 2** P.II52.5 Cement chemical composition analysis

| Project \ Chemical composition | CaO (%) | MgO (%) | $SO_3$ (%) | Ignition Loss (%) | chloride ion (%) | Alkali Content (%) | Insolubles (%) | Conclusion |
|---|---|---|---|---|---|---|---|---|
| Determination value | 0.64 | 2.17 | 2.47 | 2.06 | 0.009 | 0.58 | 0.67 | Qualified |
| Predetermined value | / | ≤5.0 | ≤3.5 | ≤5.0 | ≤0.6 | ≤0.6 | ≤1.5 | |

**Table 3** Physical and mechanical properties of coarse aggregate index

| Largest grain size (mm) | Apparent density ($kg/m^3$) | Packing density ($kg/m^3$) | Tap density ($kg/m^3$) | Accumulation void fraction (%) | Vibrated void fraction (%) | Needle flake content(%) | Crush value (%) | Silt content (%) | Clay content(%) | Absorption rate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 2639 | 1510 | 1580 | 42.8 | 40.1 | 5.9 | 7.5 | 0.4 | 0 | 0.1 |
| Conclusion | The sample inspection by project meet "The technical specification for construction of highway bridge" JTG/T F50-2011 requirements for high performance concrete with coarse aggregate. | | | | | | | | | |

**Table 4** Coarse aggregate grading

| Mesh size (mm) | 31.5 | 26.5 | 19 | 16 | 9.5 | 4.75 | 2.36 | <2.36 |
|---|---|---|---|---|---|---|---|---|
| Cumulative sieve residual rate (%) | 0 | 2.8 | 38.2 | 61.0 | 82.8 | 94.4 | 99.8 | 0.2 |
| Conclusion | The sample inspection by project meet "The technical specification for construction of highway bridge" JTG/T F50-2011 requirements for high performance concrete with medium sand distribution. | | | | | | | |

The mechanical strength of the coarse aggregate, particle shape, surface characteristics, grading, impurity content, water absorption, etc have important influence on the performance of the CF60 concrete. The selection of coarse aggregate is very important for the efficient concrete, high quality material can be used to make high performance special concrete. Therefore, choose texture hard, clean, good grain shape, good gradation, maximum nominal size appropriate gravel, can ensure the performance of concrete construction, minimizing water usage and slurry volume, improve the strength and durability of concrete.

## 2.3. Fine aggregate

Fine aggregate used in Tengxian Huang Huahe natural sand, medium sand, Particle clean, hard texture, the main physical and mechanical performance index test results as shown in Table 5, table 6.

**Table 5** Physical and mechanical properties of fine aggregate index

| Apparent density ($kg/m^3$) | Packing density ($kg/m^3$) | Tightly packed density ($kg/m^3$) | Accumulation of void fraction (%) | Tightly packed void fraction (%) | Silt content (%) | Clay content (%) | Organic matter content | Fineness modulus (Fm) |
|---|---|---|---|---|---|---|---|---|
| 2631 | 1589 | 1688 | 39.6 | 38.0 | 1.0 | 0.2 | Qualified | 2.76 |

*Corresponding author: Email: [a]gx5635604@sina.com, [b]jychxb@sina.com, [c]chenjunxiangde@126.com

| Conclusion | The sample inspection by project meet "The technical specification for construction of highway bridge" JTG/T F50-2011 requirements for high performance concrete with fine aggregate. |
|---|---|

**Table 6** Fine aggregate grading

| Mesh size (mm) | 9.5 | 4.75 | 2.36 | 1.18 | 0.6 | 0.3 | 0.15 | 0.075 |
|---|---|---|---|---|---|---|---|---|
| Cumulative sieve residual rate (%) | 0 | 4.0 | 16.7 | 38.8 | 54.6 | 80.0 | 95.6 | 98.4 |
| Conclusion | The sample inspection by project meet "The technical specification for construction of highway bridge" JTG/T F50-2011 requirements for high performance concrete with medium sand distribution. | | | | | | | |

The effect of fine aggregate on the mixing of high grade concrete is larger than the rough aggregate. Should choose grading good river sand. If the sand is too thin, satisfies the requirement of the same workability, will increase the dosage of cement. This not only increases the cost of concrete, but also causes cracks in the shrinkage, which can affect the technical performance of concrete, especially durability. But the sand also should not be too coarse, the fineness modulus is at more than 3.3, it is easy to cause the new mixed concrete to be segregation in the transport pouring process, protect the water ability is poor, which can affect the quality of the concrete.

## 2.4. Water

Concrete mixing water, natural water or clean drinking water, conform to the content of chloride ion in water is not more than 200 mg/L, sulfate content at $SO_3$ is not more than 500 mg/L.

## 2.5. Admixtures

The CF60 concrete adopts Guangxi Huangteng chemical building materials company limited production of KL - HPC retarding type high performance water reducing agent, Due to the larger dosage of cement, low water cement ratio, high strength requirement, concrete mixing fluidity big, so the design of concrete and construction put forward higher request, in order to meet the requirements of the performance of concrete and construction, at the same time reduce the dosage of cement, reduce the engineering cost, the choice of admixtures is particularly important. Admixtures is chosen mainly considered from the following aspects: delay the initial setting time of concrete, improve the early strength of concrete, decrease the loss of concrete slump, its compatibility with cement, admixtures stability and reduce concrete hydration heat, etc.

Through contrast test, choose KL - HPC retarding type high performance water reducing agent, its main technical indicators performance test results as shown in table 7.

**Table 7** KL - HPC retarding type high performance water reducing agent of quality inspection result

| Technical indicators | Solid content (%) | Density (g/ml) | PH | Total alkali content (%) | Chloride ion content (%) | Fluidity of net cement slurry (mm) | Mortar water reducing rate (%) |
|---|---|---|---|---|---|---|---|
| Determination value | 22.5 | 1.070 | 6 | 1.4 | 0.01 | 260 | 26 |
| Predetermined value | 22±1 | 1.070±0.002 | 4～6 | <10.0 | <0.02 | >240 | >25.0 |
| Conclusion | According "Concrete admixture"GB8076-2008 standard, the product the project reach the retarded high performance water reducing agent grade a index requirements. | | | | | | |

## 2.6. Fly ash

Fly ash contains the active ingredient slower than the $C_3S$ and $C_2S$ cement hydration speed, a secondary hydration can effectively fills the hole in the concrete internal structure, makes concrete internal more dense, so as to improve the technical performance of concrete. Selecting high quality fly ash can effectively improve the working and durability of concrete, save cement and reduce cost.

The concrete useIgrade fly ash is provided by Zhuhai Yuezu environmental protection science and technology development co., its main technical indicators performance test results as shown in table 8.

**Table 8** Igrade fly ash quality inspection results

| Technical indicators | Fineness (%) (45um Square hole sieve) | Water requirement than (%) | Ignition loss (%) | Sulphur trioxide (%) | Water content (%) |
|---|---|---|---|---|---|
| Determination value | 10.1 | 93 | 2.21 | 1.75 | 0.30 |

| | | | | | |
|---|---|---|---|---|---|
| Predetermined value | ≤12.0 | ≤95 | ≤5 | ≤3 | ≤1 |
| Conclusion | The sample inspection by project meet "Used in cement and fly ash in concrete" GB/T1596-2005 Igrade fly ash of the technical requirements. | | | | |

### 2.7. Steel fiber

CF60 high-performance concrete mixed incorporation a certain amount different distribution of end hook steel fiber, can effectively hinder the expansion of microcracks in concrete and the formation of macroscopic fissures, significantly improve the concrete tensile, bending, impact resistance and fatigue resistance, and have good ductility.

The selection of steel fiber concrete, and its main technical indicators performance test results as shown in table 9.

**Table 9** End hook steel fiber products quality inspection results

| Inspection items | Length deviation (%) | Equivalent diameter deviation (%) | Length to diameter ratio deviation (%) | Tensile strength (MPa) | Bending performance | Conclusion |
|---|---|---|---|---|---|---|
| Determination value | －1.2 | -4.3 | +1.8 | 640 | No fracture | Qualified |
| Predetermined value | ±10 | ±10 | ±15 | >600～1000 | No fracture | |

### 2.8. Polyacrylonitrile fiber

The polyacrylonitrile fiber and concrete has good mixed sex, CF60 high-performance concrete mixed with a certain amount of polyacrylonitrile (12 mm), which can effectively improve the shock resistance, tensile strength, crack resistance and durability, the more fiber, the smaller the distance, the stronger the anti-cracking ability, resistance to early plastic better and brittleness smaller.

The main performance and technical indexes of polyacrylonitrile fiber selected in this test are shown in table 10.

**Table 10** Polyacrylonitrile fiber quality inspection result

| Inspection items | Tensile strength (MPa) | Elongation at break (%) | Modulus of elasticity (MPa) | Melting point (℃) | Diameter (um) | Conclusion |
|---|---|---|---|---|---|---|
| Determination value | 991 | 20 | 17936 | 245 | 18 | Qualified |
| Predetermined value | >910 | >15 | >17100 | ≥220 | / | |

## 3 CF60 concrete optimization design

CF60 high performance concrete should have good workability, manufacturability, mechanical properties, stability and durability of engineering characteristics. Must be in accordance with the requirements of technical specification and engineering design, based on "The common concrete mixture ratio design regulation" (JGJ55-2011) to the high performance concrete CF60 composition design, determine the various ingredients of satisfying the engineering properties of concrete unit dosage, conduct performance test study, comprehensive evaluation of its rationality and economy.

### 3.1. Determine benchmark concrete mixture ratio

The design requirements. The strength grade of concrete CF60, mixing content slump of 160 ~ 200 mm, sand ratio of 35 ~ 45%, the initial setting time is not less than 12 h.

Design principle. Concrete mixture ratio of main design parameters are: the unit water consumption, water, cement ratio, sand ratio, can choose three different water-binder ratio (±0.02～0.03) and the sand ratio (±1% ~ 2%) accordingly combination, through contrast test, the determination of different mixing proportion of concrete slump and compressive strength, etc, the main technical indicators, thus determine the optimal dosage of the unit of the composition of the material proportion, that is the benchmark concrete mixture ratio.

### 3.2. Recommended concrete construction mix ratio.

Through a large number of experiments, the optimum mixture ratio design and field verification, recommended concrete construction mix ratio, its test results as shown in table 11.

### 3.3. The workability of concrete

The workability of the newly mixed high-flow concrete determines whether the construction of concrete site is smoothly, whether or not the quality is guaranteed, its

best effect should be to control the loss of big slump and little slump; Not secrete water, segregation resistance, good uniformity; Good pumpability, no blocking tube, no detonation tube; Good filling and tightness. Therefore, in the design of mix proportion, must focus on three main contradictions of fresh concrete mixture, that is the contradiction between big slump and little slump loss, the contradiction between deformation ability and segregation resistance, the contradiction between the liquidity and adhesiveness.

The experimental results show that the main method of solving the above contradictions effectively is: choosing the proper type of cement, the strength grade, the amount of cement, the unit water use; The variety and quantity of blended materials; The dosage of admixture and its applicability to cement; Raise sand rate, increase water retention and suitable environmental conditions, etc. The good workability of concrete is a prerequisite for the orderly construction of concrete.

**Table11** Recommend CF60 concrete mixture ratio test results

<table>
<tr><th>Raw materials</th><th colspan="2">Specifications and instructions</th><th>Relative mixing proportion</th><th>Unit consumption (kg)</th><th>Trial mix material dosage (kg)</th><th>Note</th></tr>
<tr><td>Cement</td><td colspan="2">Guangxi Huayun (Pingnan) co., LTD., P. II52.5 silicate cement</td><td>1.000</td><td>449</td><td>21.10</td><td rowspan="14">1. Sand and stone are in dry state as a benchmark, the coarse aggregate and fine aggregate moisture content are all 0%, construction according to the measured the moisture content use conversion.<br>2. This mixture is according to the selected material design, engineering parts use limited to regulation, Including the bridge piers, cable tower, box girder.<br>3. The concrete is suitable for use in the environment category for general, its effect is C grade.</td></tr>
<tr><td>Sand</td><td colspan="2">Tengxian Huang Huahe natural sand, medium sand</td><td>1.423</td><td>639</td><td>30.04</td></tr>
<tr><td>Stone</td><td colspan="2">Shiqiao Ma An Shan stone field (5-10) mm, (10-15) mm, (15-25) mm mixed macadam</td><td>2.347</td><td>1054</td><td>49.54</td></tr>
<tr><td>Water</td><td colspan="2">Drinking water</td><td>0.345</td><td>155</td><td>7.28</td></tr>
<tr><td>Admixture</td><td colspan="2">Zhuhai Yuezu environmental protection science and technology development co.I grade fly ash</td><td>0.176</td><td>79</td><td>3.72</td></tr>
<tr><td>Water reducing agent</td><td colspan="2">Guangxi Huangteng chemical building materials co., LTD. Production of KL - HPC retarding type high performance water reducing agent</td><td>0.015</td><td>6.864</td><td>0.32</td></tr>
<tr><td>Steel fiber</td><td colspan="2">Steel fiber co., LTD. Chongqing city port (End hook type)</td><td>0.174</td><td>78</td><td>3.66</td></tr>
<tr><td>Polyacrylonitrile fiber</td><td colspan="2">Taian wisdom let engineering materials co., LTD (12mm)</td><td>0.002</td><td>0.8</td><td>0.04</td></tr>
<tr><td>Test mixing water than rubber</td><td colspan="2">0.29</td><td colspan="2">Dosage of admixture</td><td>1.5%</td></tr>
<tr><td>Sand ratio</td><td>38%</td><td rowspan="2">Mixture ratio (Mass ratio)</td><td colspan="3" rowspan="2">449:639:1054:155:79:6.864:78:0.8</td></tr>
<tr><td>Mixture density</td><td>2440kg/m$^3$</td></tr>
<tr><td>Initial condensation time(h)</td><td>15</td><td>Final condensation time (h)</td><td colspan="3">17</td></tr>
<tr><td>Slump</td><td>180mm</td><td rowspan="3">The measured compressive strength (Mpa)</td><td>3d</td><td colspan="2">/</td></tr>
<tr><td>Design strength</td><td>60 MPa</td><td>7d</td><td colspan="2">65.9</td></tr>
<tr><td>Try match strength</td><td>69.9 MPa</td><td>28d</td><td colspan="2">74.7</td></tr>
<tr><td>Conclusion</td><td colspan="6">The concrete that using each performance index of all kinds of materials in accordance with the relevant specification requirements, recommend mixture ratio each performance index conforms to "Technical specification for construction of highway bridge" JTG/T F50-2011 requirements.</td></tr>
</table>

### 3.4. The mechanical properties of concrete

The mechanical properties of high performance concrete mainly depends on three aspects, one is the mechanical strength of the gelled material, the second is cementing material and aggregate interface cementation strength, The third is to aggregate their strength. When under external load, load can only be borne by the solid part of the concrete, porosity can't bear any load, micro cracks so will continue to expand, interpenetration lap as crack network; Interface transition zone also influence its role in aggregate and passed, become the best way to crack propagation and well versed in, thus significantly reduce the strength of concrete. Therefore, concrete construction should be uniform mixing, vibrating compaction, should immediately after forming the suitable temperature and humidity in curing, prevent moisture loss and the generation of micro defects.

## 4 Construction technology and quality inspection of concrete structure

### 4.1. Concrete structure construction technology

#### *4.1.1 Construction organization design*

In bridge construction organization design, combined with the scene of the topography, geology, soil quality, hydrology, climate and other natural conditions, making reasonable construction scheme, the choice of the reasonable construction method, especially the key project, key parts and important link, such as bridge foundation, bridge span structure, etc.

#### *4.1.2 Construction technology key points*

Configuration choice for raw materials of high performance concrete and its mixing proportion are have high requirements, but to ensure the high performance concrete meet the requirements of the technical performance and the use of engineering structures, main technical points of the construction and quality control is very important. Specific as follows:

**Control the quality of the raw materials.** All raw material quality inspection including four areas: in the former, after the play, before use and in use process, according to regulations frequency to sampling inspection.

**Raw material ingredients accurately.** Dosage should be automatic measurement of all kinds of materials, coarse and fine aggregate of aggregate control error within 2%, other material error control within 1% accurate configuration.

**Mixture mixing evenly.** Concrete mixing in forced mixing equipment, and strictly control the mixing time of 60 ~ 180 s, colour and lustre is uniform.

**Mixing content should have good workability and manufacturability.** Using the pumping construction technology, to ensure that meet the requirements of the construction of concrete slump, at the same time, pay special attention to slump by the problem of loss too fast, and when it is necessary to take effective measures, to ensure the liquidity and the pumpability of concrete.

**Reasonable control site construction process.** According to the concrete mixing content setting time, reasonable control site construction process; Concrete to uniform vibrating close-grained, template shall be installed in accordance with the requirements and reasonable control the time to dismantle.

**Protect wet curing.** Concrete open the template should be timely watering after moisture maintenance, and maintenance of not less than 14 days.

**Inspection and evaluation.** By using the method of scientific detection technology and concrete construction of every working procedure quality inspection and evaluation, and constantly improve the quality awareness and strengthen quality management.

**Establish a perfect quality assurance system.** A comprehensive, whole link, the whole process of quality supervision, inspection and management.

### 4.2. The engineering quality inspection and evaluation

The engineering quality inspection including process quality inspection and quality acceptance of the completion of. Quality inspection process is more important than the quality acceptance of the completion. Engineering quality test results show that the optimized design of concrete mixture ratio of high performance concrete with good workability, pumpability, mechanics, volume stability; Structure of the concrete surface color is consistent, without the voids and pits, the actual strength to meet the requirements of the design strength grade of concrete. Built the appearance quality of concrete structure and the intrinsic quality of overall in good condition. But in a complex environment, the stress conditions and construction control and so on the many kinds of damage factors, make concrete structure cracking phenomenon still is inevitable.

## 5 Conclusion

Research and practice show that CF60 high performance concrete has suitable working performance, good mechanical properties, long-term stability and excellent durability. Guangxi Wuzhou City Ring Road Fudiankou Xijiang Bridge is a long, large span bridge structure, CF60 high performance concrete on its application, effectively enhance the ability of concrete to resist the long-term damage factors, delay and reduce the early shrinkage and the emergence of cracks ,improve the engineering quality and service life of the structure, and can obtain the good investment efficiency, has good popularization value and broad prospects for development.

## References

1. GB175-2007. General Portland Cement [S].
2. JTG E30-2005. Highway engineering cement and concrete test procedures [S].
3. JTG/T F50-2011. Technical specification for construction of highway bridge [S].
4. GB8076-2008, Concrete admixture [S].
5. JGJ55-2011. Code for design of concrete mix proportion [S].
6. Qiu Yi-mei, Wang Yu-hong, Chen Jun-xiang: C50 self-compacting high performance concrete mix proportion design and engineering application[J].World Bridge, 2011, 4:61-64.
7. QIU Yi-mei, CHEN Xiao-bing:Application and popularization of highway steel fiber concrete pavement [J].Highway traffic science and technology,2011,3:70-72.