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Research Article

Interchange Design of Hub of Zhoukou South in Zhoukou of Daguang Expressway

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Abstract: This study introduces the general situation of Hub interchange design of Daguang highway in the south of Zhoukou and lists 2 design schemes, the best scheme is selected by comparison and it also introduces the design situation of the bridge, it mainly introduces bridge opening layout, technical standards, design main point and structure calculation.

Keywords: Bridge, highway, hub interchange, scheme comparison

INTRODUCTION

The hub interchange in the south of Zhoukou sets in the intersection of Daguang highway and Luozhoujie highway. Its main function is to make Daguang highway and Luozhoujie highway interconnection and to provide the traffic flow conversion services for the 2 projects. Hub interchange in the south of Zhoukou is an important part of Daguang highway; the reasonable layout of the interchange plays an important role in promoting the contact of central and western regions and economically developed eastern regions. Luozhoujie highway is bi-directional four-lane, the sub grade width is 26 m, its pavement uses asphalt concrete and the high of sub grade at the intersection is about 4.8 m 1. According to the traffic analysis, the swerve traffic of interchange is the main with the southwest quadrant and northeast quadrant, northwest quadrant and southeast quadrant is relatively small. The cross pile with Luozhoujie highway is K36+090.911, the cross angle is 129º 28'10".

Wang (2009) have a research of the road and bridge project of prestressed concrete continuous box girder construction technology. Lang (2010) studies the Cast-in-situ prestressed steel box girder bridge of roof tension and web tension comparison. Tian (2006) analyzes the rational arrangement of bridge bearings and replacement of technical research.

This study introduces the general situation of Hub interchange design of Daguang highway in the south of Zhoukou and lists 2 design schemes, the best scheme is selected by comparison and it also introduces the design situation of the bridge, it mainly introduces bridge opening layout, technical standards, design main point and structure calculation.

SCHEME COMPARISON OF HUB

Recommended scheme: The recommended scheme is a directional type scheme which is all composed of the direct and semi-direct ramps; the minimum radius of ramp is 160 m^2.

Advantages: there is no loop ramp, the index of plane linear is high, the ramp linear is smooth, it is easy to identify diverge and merge, driving conditions are good.

Disadvantages: there are more bridge structures. Figure 1 shows the plan of hub interchange in the south of Zhoukou (comparison scheme).

Comparison scheme: The comparison scheme is an alfalfa leaf variant program which is composed of the loop ramp, direct and semi direct ramp. The minimum radius of ramp is 70 m.

Advantages: the interchange type is tight; the amount of bridge engineering is smaller. Figure 2 shows the plan of hub interchange in the south of Zhoukou (comparison scheme).

Disadvantages: There are two loop ramps, the index of plane linear is lower and bypassing the distance of ramp is far.

After comprehensive comparison, directional type program is used as the recommended program. Table 1 makes a comparison scheme table of hub interchange in the south of Zhoukou.

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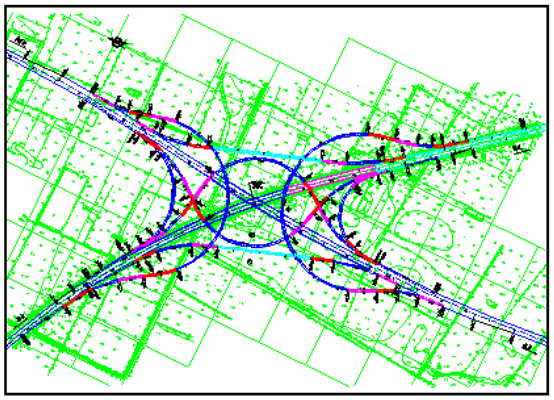

Fig. 1: The plan of hub interchange in the south of Zhoukou (comparison scheme)

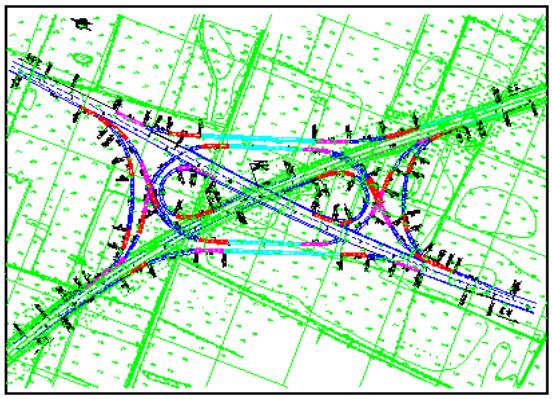

Fig. 2: The plan of hub interchange in the south of Zhoukou (comparison scheme)

DESIGN OF HUB INTERCHANGE IN THE SOUTH OF ZHOUKOU

By cross bridge:

Bridge opening layout and technical standard: The cross pile which is crossed by cross bridge of hub interchange in the south of Zhoukou and Luozhoujie highway is K36+090.911. The length of the full-bridge is 886 m; it's divided into 3 units. The superstructure of the first and 3 units of the bridge adopt fabricated part prestressed concrete continuous box girders, the span composition of the bridge: first unit is 7-30 m; third unit is 8-30 m. The superstructure of the second unit adopts cast-in-place prestressed concrete continuous box-girder, the composition of the cross-bridge: the left half amplitude is (35+4×39.99+50+2×39+3×35) m; the right half amplitude is (3×35+2×39+50+4×39.99+35) m^3. The under part of full-bridge adopts column piers and ribbed plate type abutment. The full-bridge adopts the bored pile foundation. The bridge horizontal is located in the right partial round curve that radius is 5500 m and the left partial round curve that radius is 6473.24 m. Design technical standard: calculating running speed: 120 km/h. Design load: car-over 20 level, trailer-120. Earthquake intensity: the basic intensity is 6º.

Design main point: The superstructure of the first and 3 units of the bridge adopt the fabricated part prestressed concrete continuous box girders, the cross section of superstructure of the second unit adopts single box with 2 chambers, the height of prestressed concrete continuous box-girder is 2.4 m, the web adopts the same height, deck transverse slope is formed by the overall rotation of the box-girder 4. The thickness of web is 45-65 cm. The cantilever length of box girder is 2.4 m, the roof thickness of the mid-span section is 25 m and the thickness of the bottom plate is 20 m. Prestressed tendons are divided into web prestressed tendons and roof and bottom plate prestressed tendons, the web prestressed tendons adopt 270 grade strands of ASTM 19Φj15.24 mm and 10Φj15.24 mm with anchorage of OVM (A) l5-19 and OVM (A) l5-105. The roof and bottom plate prestressed tendons adopt 270 grade strands of 5Φj15.24 mm of ASTM-92 with anchorage of BMl5-5. The under part all adopts column piers and ribbed plate type abutment, foundation all adopts bored pile.

The computational analysis about the upper girder structure of second unit and the substructure of full-bridge: The calculation of upper overall structure adopts the comprehensive program of bridge structure "Dr. Bridges" V2.9, the calculation content is the

Table 1: Comparison scheme table of hub interchange in the south of Zhoukou

		Recommended scheme	Comparison scheme
Cross way		Main line cross	Main line cross
Interchange way		Directional type	Alfalfa leaf variant type
By cross road name and grade		Luozhoujie highway	Luozhoujie highway
Earth work quantity (m^3)	Fill	975092	847891
	Dig	31587	27581
Site area (mu)		720.96	652.12
Ramp	Design speed (km/h)	50	50
	Minimum radius (m)	160	70
	Maximum longitudinal slope (%)	-4.1	3.7
	Full-length (m)	10610	7893
Flyover (m/seat)		3927.76/5	2881.30/7
Culvert (m/way)		150.50/6	115.00/4
Budget amount (ten thousand Yuan)		17175	17716

calculation of effect which is composed of the role of structure weight of the finished bridge state, prestress, concrete shrinkage and creep (they are calculated according to 1000 days), supports forced displacement (it is considerate according to malocclusion pier settlement and settling is considered as 1.0 cm), live load, temperature change (heating and cooling each by 25ºC, the heating and cooling of bridge deck is calculated according to the temperature field which is ruled by the Design Code of Reinforeed and Prestressed Concrete for Highway Bridges) etc and the calculation of the construction phase 6. Load combination is combined according to the General Specification for Highway Bridge and Culvert Design. The box girder transversal is calculated each according to the 2 kinds of structure model of fix end effects of the frame and simply supported plate and the large control of cross section to design is choosed. Analysis calculation of the internal force of substructure adopts the substructure analysis procedure of the bridge. Horizontal force of each pier is divided according to stiffness; the internal force of foundation pile is calculated according to the "m" method and designed according to the friction pile.

Ramp bridge:

Bridge opening layout: The hub interchange in the south of Zhoukou total sets A, B, G, H four ramp bridges. The cross pile of a ramp with Luozhoujie highway is AK 0+680.838, the start pile of Ramp Bridge is AK 0+434.338, the end pile of Ramp Bridge is AK 0+927.338, total length of the bridge is 493 m and full-bridge is divided into 3 units. Span combination is (6×28) + (2×28+38+2×28) + (6×28) m. Each unit adopts cast-in-place prestressed concrete accordant continuous box girder, the beam height is 1.8 m; The cross pile of B ramp with Luozhoujie highway is BK 0+664.920, the start pile of ramp bridge is BK 0+419.420, the end pile of ramp bridge is BK 0+912.420, total length of the bridge is 493 m, full-bridge is divided into 3 units. Span combination is (6×28) + (2×28+38+2×28) + (6×28) m. Each unit adopts cast-in-place prestressed concrete accordant continuous box girder, the beam height is 1.8m; The cross pile of G ramp with Luozhoujie highway is GK 0+964.977, the start pile of ramp bridge is GK 0+550.477, the end pile of ramp bridge is GK l+463.477, total length of the bridge is 913 m, full-bridge is divided into 6 units. Span combination is 2× (6×28) + (2×28+38+2×28) + 3 × (5×28) m. Each unit adopts cast-in-place prestressed concrete accordant continuous box girder, the beam height is 1.8 m; The cross pile of H ramp with Luozhoujie highway is HK 1+036.933, the start pile of ramp bridge is HK 0+622.433, the end pile of ramp bridge is HK l+619.433, total length of the bridge is 997 m, full-bridge is divided into 6 units. Span combination is 2 × (6×28) + (2×28+38+2×28) + 3 × (6×28) m. Each units adopts cast-in-place prestressed concrete accordant continuous box girder, the beam height is 1.8 m.

Technical standards: Calculating running speed: 80 km/h. Design load: car-over 20 levels, trailer-120. Sub grade width: 8.5 m. Skew angle: 90°. Earthquake intensity: the basic intensity is 6º.

Design main point: The upper structure adopts the prestressed concrete continuous box girders. The section adopts single box and single chamber; box girders all use straight web plates. The roof and bottom plate of box girders adopt parallel design, deck transverse slope is formed by the overall rotation of the box girder and the change of elevation of support cushion block. (2.0 m) width of reinforced concrete middle cross beams are set at the top of both sides of the pier of 38 m of the main span and No. 18 pier of G ramp, No. 18 top of H ramp, other non-connected piers set reinforced concrete middle cross beams of the width of 1.5 m; The end cross beams of the width of 1.2 m are set in the abutment and the end beam of connecting pier. The ramp No. 5, 8, 9 pier and B ramp No. 8, 9 pier and G ramp No. 14, 15 pier and H ramp No. 14, 15 pier are single column piers and single supports; G ramp No. 18 pier, H ramp No. 18 pier are wall type piers and single supports; Other piers are double column and double bearings. Abutment adopts ribbed plate type abutment; Foundation adopts pile foundation.

When selecting type of support, the middle of the pier of a unit sets fixed support, abutment and connection pier set a unidirectional sliding bearing and a bidirectional sliding bearing, other piers set longitudinal unidirectional sliding bearings 7. The sliding direction of bearing should be consistent with the route centerline; sliding direction of the unidirectional sliding bearing should be consistent at the same beam.

The inside of box girder webs of prestressed tendons set anti collapse reinforced, the anti collapse reinforced should hook at the web stirrup, hook point should be at intersection of the cross of steel bar.

SUPERSTRUCTURE CALCULATION

Internal force calculation: The calculation adopts the comprehensive program of bridge structure "Dr. Bridges" V2.9. Bridge deck calculates according to the unidirectional plate and the cantilever plate. the calculation content is the calculation of effect which is composed of the role of structure weight of the finished bridge state, prestress, concrete shrinkage and creep (they are calculated according to 1000 days), supports forced displacement (it is considerate according to malocclusion pier settlement and settling is considered according to 1.0 cm), live load, temperature change (heating and cooling each by 20°C, the heating and cooling of the bridge deck is calculated according to the

temperature field which is ruled by the Design Code of Reinforced and Prestressed Concrete for Highway Bridges) etc. and the calculation of the construction phase. Load combination is combined according to the General Specification for Highway Bridge and Culvert Design. The box girder transversal is calculated each according to the 2 kinds of structure model of fix end effects of the frame and simply supported plate and the large control cross section to design is choosed.

Prestressed system: Prestressed tendons are divided into web prestressed tendons and roof prestressed tendons, the web prestressed tendons adopt 270 grade strands of ASTM 13Φj15.24 mm with anchorage of OVM (A) l5-13. The roof prestressed tendons adopt 270 grade strands of 5Φj15.24 mm of ASTM-92 with anchorage of BMl5-5.

Construction phase: The first unit of main span of ramp bridge adopts at both ends of the symmetrical span-by-span construction, the construction joints are set in every hole (except the main span) about 0.2 L from the fulcrum, the longitudinal prestressed tendons adopt staggered tension, that is the first construction of the main span box girder, half steel tendons are tensioned at both ends of construction joints and linked the connector and then of the second, four-hole is constructed, other half steel tendons are tensioned at both ends of construction joints, at last the first, five hole is constructed , all steel tendons are single-ended tensioned at beam ends. The other box girders adopt cast in place span by span, longitudinal prestressed tendons adopt staggered tension, construction joints are set in every hole about 0.2 L from the fulcrum except the first hole, every time half steel tendons are tensioned at both ends of the construction joints and linked the connector, the other half prestressed tendons are left to the next construction phase to tension, it should be so staggered tension until the anchor of beam ends of each joint.

SUBSTRUCTURE CALCULATION

Horizontal force calculation: Considering the anti-push rigidity of bearings and column, their combined anti-push rigidity is adopted the calculation of the horizontal force in the allocation of each pier top.

Internal force calculation for pile foundation: They are calculated by “m” method, the full-bridge pile foundations are all designed by friction piles.

CONCLUSION

Hub interchange in the south of Zhoukou is a four layer all directional interchange, the design of interchange speed and service levels are higher, the bridges within interchange are curve, slope, skew bridges, which make the design more difficult. All the bridges are selected cast-in place box type continuous beams whose building height is lower and they are appropriate for curve, slope, skew bridges. Except using single column pier at the cross line, others use double column, which effectively decreases the structural torsional deformation and makes the bridge look like lightweight, attractive and durable.

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