Geological route selection for the Neijiang-Kunming railway along river valleys

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Abstract: The Neijiang-Kunming railway, a single track railway, is a Chinese national Class I railway. The segment of the railroad between Shuifu in Yunnan province and Meihua Mountain in Guizhou province is a new construction, whose total length is 357.643 km. In the river valley of the new part, there are a lot of geological constraints, mostly in the section from Shuifu to Daguan. These engineering geological problems can influence or control the railway route selection include slope cuts, talus deposits, unstable rock masses, and mudflows. In the route survey and design process, many studies had been carried out to select the optimal route. Geologic bodies of poor geotechnical quality were identified as to their route-intersected length and complexity. Alternative routes were compared for their need for cuts, tunnels, and bridges and the selected routes mostly using the avoid poor geologic conditions. Where avoidance is impossible, the selected plan tries also to be advantageous in terms of ground stabilization and piling, cable earth-retaining walls and other engineering improvement methods. As a result of the geologic route selection studies, the selected route will require engineering action for about 20 km (40 percent) of the 50 km of total length. The forty percent improvement length means that the geological factors are important in the project, and demonstrates that identification and comparison of geological solutions is a reasonable requirement in the selection of railway alignment for the river valley part of the rail line, and that the resulting engineering improvements methods are usable and effective.

Résumé: Le chemin de fer de Neijiang-Kunming est la ligne unique de la classe nationale. Le début nord est à la section Neijang du chemin de fer Chengdu-Chongqing. Le final est à la ville Kunming. Dont la section du Fushui de Yunnan au Meihuashan de Guizhou est la section nouvellle construite. La longueur totale est de 357.643KM. La géologie mauvaise de la valée se traouvant à la section de Fushui-Daguan est bien développée. Le problème géologique principal des travaux qui influence le choix de la ligne est le glissement de terrain, le tas de roche, le pendentif et la coulée boueuse. Pendant la période de la prospection et de la conception, on a profondement, macroscopiquement et partiellement étudié, choisi et comparu le projet et la direction du projet pour la section de mauvaise géologie dans la région de valée. On a pris le principe de « couper la courbure et choisir le direct », « creuser le tunnel vers l'intérieur », « construire le pont vers l'extérieur » pour décider le choix et la comparaison du projet. Principalement, on a pris la méthode de faire le détour et de s'écarter. En ce qui concerne la section qui est difficile de faire le détoure et de s'écarter, selon la comparaison et le choix concret de la ligne, on a choisi le projet stabile. Et on a aussi établi le pieu, l'ancrage et le mur de soutènement etc, comme la mesure de protection. La longueur accumulée de choix et de comparaison est de plus de 50KM. Pour le choix de la direction du projet, on a réfléchi suffisament le facteur géologique. Il y a de plus de 20 endroits qu'on a changé la direction à cause du problème géologique. Ça signifie l'importance du choix de la géologie. L'exécution et le recollement des travaux du chemin de fer de Neijang-Kunming a montré que le choix et la comparaison de la géologie des travaux du projet dans la région de valée sont raisonables. La mesure des travaux qu'on a prise est effective et passable.

Keywords: river valley part; poor geological condition; geological selecting plans; comparing Neijiang-Kunming railway

INTRODUCTION

The Neijiang-Kunming railway, single track railway, is our national Class I route, which begins at the Neijiang railway station of SiChuang Province, via YiBing, ZhaoTong, LiuPanShui to the South Kunming railway station. The segment of the railroad between Shuifu in Yunnan province and Meihua Mountain in Guizhou province is a new construction, with total length is 357.6 km.

The new construction route marches forward from the edge of Szechwan basin, Suheng River and its tributary, the Luoyi River. After arriving at DaGuang, it the selected route gradually leaves the river valleys and climbs close along the slope and up to the Yun Gui plateau. The topography is high in the south and low in the north in whole, with precipitous surface and great topographic relief, among which the north of DaGuang is medium-lower hill valley landform, with the altitude rising from 300 m at Shuifu, up to 700 m at DaGuang. After DaGuang, the route is back and forth along the transition belt of Wumengsha section, from the Szechwan basin to high plain of Yu Gui, then climbs to the plateau from the break in slope, to a maximum elevation of 2100 m amsl.

The River Valley segment is the reach from Shuifu to Daguang, 137.6 km in length, following a gradient of 6‰, 450m in minimum curve radius, and 850m along of the departure line. There are 13 stations, 89 bridges with 18943

meter tracks, 42 tunnels with 67977 meter tracks, and the total length of bridge tunnel is 86920 meter tracks which accounts for 63.17% of the route. Moreover, the key route projects are Qinglong Bei turnnel (4104m), Huanglian Po Turnnel(5306m),Yanjing 1# turnnel, Podu He turnnel, Shasha Po Hengjiang 7th three line bridge and crossing the Tantou landslide.

OUTLINE OF THE GEOLOGICAL ENVIRONMENT

The segment from Shuifu to Daguang is known as the River Valley section. The route from Shuifu to Tantou is 44.1km in length and can be categorized as traversing lower hills, i.e. with the characteristics of straight, medium-curve alignment and occupying a "U" shaped valleys. The river valley is bounded by steep hillsides, the round-shaped hills, and exposed bedrock and scattered class I terrain, with elevations of 300-800 m, and a topographic relief of 50-200 m, and bordering hillsides of 20°-30° slopes. Generally, the route itself occupies passes through flat landss and gentle slopes have been reclaimed to dry land agriculture and rice paddys.

The route from Tantou to DaGuang passes through the eroded middle-low hill valley section, at 93.1 km length. Its riverbed appears in "V" shape with steep bounding slopes. The narrowest width of the riverbed is only about 20 m, distributing the I class terrain intermittently, with elevations of 600-1500m, and local topographic relief of 50-200 m and adjacent hill slopes of 25°-50°. The hills in the area are mostly barren, and reclaimed to dry land.

The south of Daguang can be categorized as eroded middle-hill valley terrain, where the route gradually deviates from the river valley terrain. This section is characterized by high mountain and deep valley terrain, with great topographic relief, and the route tries to adhere to the ridge lines which are affected by the geological structural lineament and local karst landforms, with surrounding elevations variations of 650-2500 m and relief ratios of 500-1000m, and natural hill slopes of 30°-80°. Most bedrock is exposed, without soil regolith, as cliffs and crags. What soil exists has been reclaimed to dry land for agricultural purposes.

Geologic strata of the River Valley segment range from Silurian to Quaternary in age. The Shuifu to Pudu River segment is underlain mainly by the sandy red shale of the Jurassic and Cretaceous Systems. After crossing the Pudu River, the route encounters mainly a rocky carbonaceous basalt with shale interbeds and some coal measures of Silurian to Quaternary ages. This rail section encounters patches of Quaternary mass-wstage deposits, such as rockfalls and colluvium, but rarely only passes across fluvial sediment.

The River Valley belt crosses two tectonic zones of the Yangze paraplatform in structure:

Szechwan Taiao: The segment is from Shuifu to Pudu river, composed of a series of broad folds in N55°-80°E trending , with underdeveloped ground fracturing. The route and the tectonic lines cross in large-angle, approaching perpendicularity, while passing through rock units of small-angle sedimentary bedding.

Shangyangzi-Diandong-Xiaxitai route: South of Pudu River to Daguang station, the route passes through bedrock with geologic structure in the form of a series of NE or nearly EW trending, unsymmetrical folds, generally steep on north faces and mild on south hillsides. Most folds intersect with the route at a large-angle, which does not produce too many route design effects. However, some folds are paralleled or nearly skew with the route in a small-angle, thus, the route has been threatened by "bedding". These faults cross the rail line at a large-angle so that the width of structural design influence of individual faults, in crossing the route, will be minimal.

The earthquake intensities along the line are mostly VII degree. Near DaGuang, future earthquake motion can be expected to act intensively, as there is an historic 7.1 Richter earthquake and the resulting earthquake intensity for the Dousha to Penghe segment is rated as VIII degree.

MAIN ENGINEERING GEOLOGICAL PROBLEMS AND ROUTES SELECTING PRINCIPLES FOR THE NEIJIANG-KUNMING RAILWAY ALONG THE RIVER VALLEYS

Poor geological conditions centralize on the Neijiang-Kurming Railway along the river valleys with large-scale potential impacts caused by gravitational geological process. The engineering geological problems that can influence or control the railway selecting scheme are landslides, talus falls, unstable rock masses, mudflow, 'bedding' plane slides.

Landslide

Project geologists have identified 40 landslide masses along the river valley route, with generally 6-60 m in thickness, classified as two major types. Landslide of unconsolidated material and bedrock masses are expected, mostly along the outcrops of sandy shale. The landslides happened in the basalt terrane, intensely influenced by tectonics, are relatively centralized as large-scale masses, but rarely occur in limestone areas. Some of colluvial landslides are large-scale, such as the LiangWan and Shuifu Station masses; but most bedrock landslides are consequent landslides, such as larger ErPingzi and Tantou landslide. In addition, near the fault, landslides are smaller and more numerous, relating the greater degree of fracturing in the tectonic zones. For example, there are 17 big or small landslides developed around 10 m in the banks of Pen River, with volume from 80×10^4 m^3 to 600×10^4 m^3. Especially, the Touzai landslide of September, 1991, the volume of which was up to 1800×10^4 m^3, buried a small village and killed 216 citizens.

Most landslide lines have been stable except few in the creep development stages. The selected plan applied to many great active landslides is mostly pass-by; however, there are still some parts of the landslides line difficult to

pass-by, due to terrain, route conditions, and economic requirements and so on. With respect to latter situation, the selected plan is adopted to pass the specific line, which should be advantage to the stability of the project. Then reasonable engineering prevention measures should be taken, such as Tantou landslide, Yanjin county landslide, South Yanjin landslide and so on.

Tantou landslide

Tantou landslide, located at the right bank of Heng River, is the sandy shale stratum of Jurassic System which is hard-soft and trends towards the left bank. The landslide shows a round-backed armchair landform, with principal axis of 620 m in length, 300~500 m in width,10~60 m in thickness. Moreover, this landslide mass occupies about 12 million cubic meters, among which the sliding area is carbonaceous sandy shale moving on a slip bedding plane contact with thick sandstone, all inclined at 15°-20°. The slide toe has extended into the present riverbed about 20m below the sliding plant. Tantou village, located above the ancient landslide, is a built-up area, yet without any ground deformation. It is indicated that the slopes are now in a state of quasi-stability. In order to maintain the stability of this ancient slide mass, it has been determined to place the railroad line on a compacted earth embankment in the river flood plane and not to disturb the slide mass. As it is, the current roadbed of the original Neijiang-Kunming railroad will be abandoned, in the interests of maintaining hillside stability.

Landslide of Yanjing County

This segment crosses Yanjin County, on a route placed above the ancient landslide in this area. Human habitation already is represented by dense building on narrow ridges. In the original project, the Yanjin 1# tunnel was plannded to be constructed through the upper-middle part of the landslide, which is only 20 m lower than the known sliding surface. This plan would have the crown of the tunnel lying at a depth of only 40 m below the surface of the unstable slide mass. In order to avoid damaging the existing surface buildings it was felt necessary to move the alignment and to lengthen the tunnel so that it now will pass through the back edge of the landslide, which guarantees the operational safety of the new railroad tunnel and of the surface buildings.

Landslide of south Yanjing

The major landslide here is of a double mass and with a typical round-backed armchair landform shape. The length, width, thickness and the volume of the principal axis are 500 m, 400, 30-75 m and 10 million m^3, respectively. This large, ancient, bedding-plane landslide has a tongue of which extends into the Heng River bed and is subject to continual fluvial erosion and reactivation. The front edge hunches and appears like a hillock, and the back edge forms a classic crown depression landform. Individual slide masses can be divided in to block-rock and soil and also large sliding rocks. Sliding occurs along a zone of soft, plastic, sandy clay intercalated with breccia, with the sliding surface steep on the upper extent and mild on the lower, inclined minimally at 10°-20°. The upturned heading edge shows some backward tilting, with no deforming phenomenon observable on most of the landslide surface. The original design concept was to adopt to set the train station and the railroad bed in an excavation to solve the need to borrow soil for the approach embankments, fore and aft. By analysis, both methods would disturb the landslide stability, thus, it was decided to adjust the position of the station so that it will sit outside the slide mass.

Talus

There are more than 90 big or small talus fans along the hillsides of the River Valley, mostly occurring in the medium-lower hill segment from Shuifu to Tianxingyang. There are another distribution of more than 60 talus fans in the medium or lower hill valley from Tianxingyang to Zhaotongyueling area. The roadbed was to cross the bodies of 58 of these talus fans and the tunnel run would have to cross 28 of these, and the planned bridges would be near another 28 talus fans. The talus is characterized by high percentages of heterogeneous rock blocks with the complex structure of a polyphase formation. Generally, talus axes are 50-1000 m in length (perpendicular to the route), 100-2000m in rail-crossing width, 50-60m in thickness, and with volumes of 10×10^4 m^3 to 4000×10^4 m^3. Some large accumulation bodies have touched or pushed into the riverbed, and have caused make the ancient river channel to circumvent them.

Talus fans were formed from continuous down-cutting of the river, in the high and steep air face forming in the natural slope or the bank slope of river valley. Under the certain tectonic and lithologic conditions, the rocky body losses its stability and forms various shapes over long periods of geologic.

Most of the talus fans appear to have formed over such long periods of geologic time that they now appear typically stable, where not aggravated by construction cuts. However, talus slope conditions at the Daguang station will require special engineering attention, commensurate with it geologic character and the needs of the railroad.

Daguang station talus: Daguang station is located in the Zhongshan valley, and area of characteristically steep landforms. The bedrock, greatly influenced by terrain, forms large talus fans after long periods of gravitational attraction. The fan has an axis 300-460 m in length, 1040 m in width, and is 5-30 m in thickness. The talus mainly consists of rock blocks, inclined in masses at about 10°-25°of the surface, on a cross slope of 20°-30° of the bedding profile grade and 5°-10°of its middle-low part. The talus does not intercalate with weak layers, ground water does not develop and is in the state of stability. The back edge hill is stable, and without any apparently dangerous rock fall potential. After geologic comparison, the selected route the one that passes through the middle-lower part of the mild talus of the bedding. Some engineered retention will be applied to protect the route security, such as piles, cables, and earth-retaining walls.

Unstable Rock Blocks as Individual Rock Falls

Various masses of unstable joint-bounded rock blocks are distributed along River Valley, mainly in the segment from Shuifu to Tianyang River, at about 45 locations along 9000 km. Factors contributing to instability are: 1) the escarpment formed by sandy rock in huge and thick bedding layers, 2) limestone and dolomite rock in general, 3) the collapse of rock bodies caused by structural veins, 4) stress-release fracture and the effects of weathering, and 5) interbeds of sandy shale rock. Due to the recessive "groove" by differential weathering of shale, when the depth of which gets to a certain magnitude, joint blocks of overlying sandstone fall by gravity. For example, the Jurassic System Layer, in the section from Shuifu to Podu River, can be divided into 5-7 sedimentary rhythms, each of which has a layer of deep-great deep sandstone which outcrops at elevations above the alignment, and greatly affect the line with individual, tumbled rock blocks. In addition, in the early, the rockfall above accumulates on the hillside brim, and in rainy season, when surface water washes-out the front edge earth of the rockfall, it can dislodge individual rock blocks again to the lower positions. With respect to the section where dangerous rocks are relatively centralized, the route can be adopted the pass-by measures.

Mudflows

There are 11 places were mudflows occur along River Valley, mostly along the Heng River and Luoyi River banks. In order to avoid the effects of mudflows, the route will be elevated to bridge across these recurring locations.

ENGINEERING GEOLOGICAL SELECTION OF RIVER VALLEY LINE IN THE TYPICAL SEGMENT

Feasibility study, preliminary and technical design, must have attention to meet the identified geological constraints, bringing about a number of changes over about 20 km of the route.

Selecting plans of roadbed and bridge tunnel

The curve cut-off, tunneling, bridging and other plans had been compared to choose the proper plan for the 19th segment from Shuifu to Daguang. The length of the comparing and selecting sector of total railway road is about 50 km. There are some typical segments below:

Selecting plans of roadbed along river and tunnelling in by

Huanglian Po Tunnel: these studies date back to the end of the1950s. The route goes along the right bank of the Heng River, while the line runs thousand meters steep landform continuously along the river, with cliffs 100~200 m high. The stratum of the route is thick sandstone intercalated with thihbedded of Triassic Xujiahe Formation. It is located in the anticline axis of Huanglianpo, with wide shear zones. Isolated rock falls are very common, some zones being typified both by high frequency and large sizes of individual blocks. It is difficult to arrange a comprehensive engineered solution to the rockfall problem. In addition, during the annual rainy season, a serious of natural seepage channels open up, appearing as waterfalls, some of which dislodge rock masses and fling them straight down onto the roadbed below. After comparing select plans to deal with all identifiable unstable slope rock, we choose the alternative plan of moving the line into the now-proposed Huanglianpo tunnel, of a by-pass length of 5260 m. This will increase the investment, but the plan avoids entire area of poor geological conditions, once and for all.

Shanxian Tunnel: This segment encounters interbedded Jurassic-aged sandstones of the Siaximiao Formation. Differential weathering dominates here and creates a third-class cliff, 4 km in length, surmounted by a 20-30 m thick single layer, while the first grade is up to 200 m thick. This cliff presents many potentially lose labile rock blocks, with diameters of 0.5-3.5 m. In the rainy season of each year, rockfalls are common and now there are two large talus fans, with overall dimensions of 180-400 m in length, 70-960 m in width, and 5-40 m in thickness. Fresh rock falls are continuously occurring. The original route alignment was to follow the edge of the river, passing at elevations below the talus fans and the trajectory paths of the individual rock-fall blocks. Our re-evaluation however, leads to adoption of another by-pass tunnel, this one of a length of 3600m.

ShoupaYan Tunnel: This tunnel is planned to avoid the consequences of disturbing a huge landslide, the principal axis of which is 1200 m in length, 300-500 m in width, and 20-50 m in thickness. The landslide is composed of a huge body of sliding rock fragments, the front edge of which extends into an ancient and now dry riverbed and then into the present, active riverbed, causing the river channel to narrow abruptly. There are nine fractures on the sliding body. The original plan was to pass the roadbed around the front edge of the landslide. By comparison, the railroad placed in a tunnel below the unstable mass will require 3055 m of such construction.

Curve cut-off and tunnel instead of road

Pudu River Tunnel: this route follows the right bank of the Heng River. The original route was to use open embankments and only short tunnels to by-pass curves of the river. The portals of these tunnels are in various types of bad ground, with such poor geological conditions as labile rock masses, taluses, and mudflows. In this segment the Heng River forms a great volte-face changed from SW to SE in this section, there are conditions to make the line straight. By comparison, the entrance terminal, located in roadbed adhere to river of the disadvantage geological position plan, is abandoned, and the line is moved inby and kept straight.

Route outwards and bridging instead of road

KaichangGou 2# Great Bridge: the line is parallel with the right bank of Heng River, with steep landform, developed joints in part of the slope and the distributing taluses and labile rock masses. This section includes a station that cannot be relocated because of cultural aspects and so an inby tunnel is not a viable option. So here, we have recommended a 580 m bridge to be placed around the toe of the unstable ground and following the river bank.

Selecting plans of left and right bank levels of river valley

The line runs along the Heng River and Luoyi River of valleys, and crosses the Heng River seven times and the Luoyi River three times. These river crossings are made necessary by terrain characteristics and to avoid contact with geological constraints. Each of the following sections is controlled by specific geological constraints.

Selecting plans of left and right banks of Heng River from Shuifu to XiaoErping

This section is characterized by 25km of Jurassic shaly sandstone with an adverse bedding of 10°-20°. The "bedding" terrain of the left bank is milder, while the cutting-bed terrain is steeper. The original Neijiang-Kunming railway runs along the left bank and most bridges and culverts have been in shape. But the left bank is disturbed by the huge, active landslides at Dawuji, Mashandan, Jiulongba, and Xintan. And the segment is located at bedding bank, so part of the section has the "bedding" problem of cutting slope and removing the soil. The geological condition is obviously benefit, only labile rock masses and miniature taluses exist partly. By geological comparison, it is decided to adopt the plan of building at the right bank.

Selecting plan of left and right banks of Heng River of Hongshaping

The line was originally designed to run along the right bank, but this would have encountered huge talus bodies. When explored carefully, the talus was found to exhibit poor stability over its body, which was 400m in length, 550m in width, 10-40m in thickness, and inclined at 27°-35°. This talus substance is relatively loose and exudes groundwater appearing frequently at the toe, which has collapsed in two spots due to river erosion. We have recommended the construction of two straight tunnels in order to avoid the influence of talus on performance of this part of the railroad.

Selecting plan of left and right banks of Cha River

Both banks of this section are affected by geologically bad ground, phenomena, such as talus, distributed in both banks, and the presence of labile rock masses along the slope crown of 1400 m of the right bank, where which is divided into 3 layers of this jointed, blocky rock occurs at upper, medium and lower elevations of 400 m, 600m and 800 m above the line respectively. These dangerous rock blocks are of general dimensions of 0.3-2.5 m, with some reaching up to 5 m. The rainy season activates the rockfalls, which greatly threaten the line and difficult to repair. Mudflows also occur along both banks (5 on the right, 4 on the left). Although the scale of these rockfall sources is not too large, the longitudinal slopes are steep, with short trajectories toward harming the railway.

In the view of these complicated geological conditions, the local rail station is also subject to impacts from the rock falls. The recommended plan is to build the railroad tracks along line at the right bank, the line passes by roadbeds and bridges, which will be broken passively and extremely difficult to prevention and cure. The roadbed of taluses section goes across mainly by removal of the soil, with poor stability of loose taluses substance in the slope and large investment in the protection project. On the other hand, the plan of the left bank is proposed to cross Heng River, and then pass-by the poor terrain such as gullies and taluses by two tunnels. Compared the two schemes, although the tunnel built by the plan of the left bank increases by 609 m and project investment increases by over 4000 thousand Yuan, the threaten from poor terrain can be avoided and hidden troubles can be eliminated. Therefore, the plan of building line at the left bank is adopted.

Selecting plan of Pan River, poor geology concentrated along the route

The Neijiang-Kunming railway follows the Pan River, which is a fault-developed valley occupied by the river. The Ermeishan Basalt has filled portions of the valley and the older bedrock also is affected by the Pan River fault and another regional parallel fault. The result is that the bedrock is tectonically fractured and the weathering approaches 30m in places, and the resulting poor slope has manifested as 6 landslides. Short tributaries join the Pan River and fragmented basalt provides solid mater for mudflows, from both sides of the valley. There are 4 active mudflows and other mudflow fans are distributed around the mouths of most of the tributaries.

The most serious problem is presented by the huge, developed landslide. Once a landslide section blocked Pan River, and is still depositing debris to the river section. In recent years a extremely large scale clastic flow slide destroyed an entire village, with serious casualty and other disaster results. According to this, it was proposed that the bad ground of the entire Pan River route be avoided, and after much field geologic research, the present Xinzai plan of avoiding the Pan River section was selected.

CONCLUSION

The Neijiang-Kunming railway, single track railway, is our national Class I route, which begins at the Neijiang railway station, and the terminal is Kunming railway station. The segment of the railroad between Shuifu in Yunnan province and Meihua Mountain in Guizhou province will be of new construction, with a total length is 357.643 km.

The whole line is complicated by adverse geologic and terrain conditions, with altitude climbs from 300m to 2260m. The general landform classification is: 1) hill area, highly eroded; 2) medium-slope lower hill valley section; 3) upper-medium hill valley section; and 4) eroded medium-slope lower valley section. Lithology of this Paleozoic to Mesozoic zone, varies mainly from clastic to carbonate sedimentary rock in the river valley of the new part. Geologic constraints plague the route from Shuifu to Daguan. Those engineering geological problems which influence or control the railway selecting scheme are steep slopes, talus masses, labile rock masses, and mudflows. In the feasibility and preliminary design stages, alternate routing was considered toward selection of the final route map. The selection and comparison studies concentrate on differentiating the bad ground into relative volume, degree of complexity or heterogeneity, and whether or not the feature was localized or widespread. Corrective measures were also considered to by-pass the bad ground, or to apply such ground improvement as ground stabilization, pile supports, cable-stayed earth-retaining walls. The special treatments are to be applied along about 50 km of the total route. Route deviation was applied to about 20 km, in recognition of geologic constraints. To date, these improvements that comparison of geological comparing solution provides a reasonable method of railway route selection.

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