Reply comments on reviewer 1#:

Specific comments

1. The title deviates from the focus of the study. The dominant thermal impact of engineering activities on permafrost origins from the embankment itself (e.g., type), while the vegetation layer should be secondary issue. A more precise title is required to address the role of vegetation layer.

Reply: Thank you. I still find a more precise title to reflect the issue of our manuscript. Title is revised as following:

Thermal impacts of engineering activities and vegetation layer on permafrost in different alpine ecosystems in Qinghai-Tibet Plateau, China

2. Line 157-161 in Section 3.2: an increasing trend of permafrost at a depth of 10 m beneath embankments in both alpine meadow and alpine steppe systems is deduced for overall observations at all sites by using a linear regression. However, concerning the delaying response of permafrost temperature at 10-m depth to previous climate warming and later engineering effects, the regression can mislead the trend. For instance, after an evident increasing trend, a slight decreasing trend occurs after around 2010 at sites FHH1 and BLR2 in Fig. 7a, CMR1 and CMH1 in Fig. 7b. The effect of engineering activities at these sites might be over that of climate. Otherwise, it means the temperature-controlling measures for the QTR failed at these sites. Please clarify the sentence in Line 168-169. This point is a major comment.

Reply: Thank you for your opinions. But, these sites which we chose is general embankment without no measures, thermal disturbance of engineering activities is gradually becoming lower. So, the decreasing trend after 2010 is attributed to climate change. So, we revised into:

While, the effect of engineering activities on permafrost is gradually becoming lower. Therefore, the effect of climate warming on permafrost at that depth beneath embankment might be stronger than that of engineering activities.

3. Line 178-189 in Section 4: the variation of soil temperature with depth beneath embankments in the alpine meadow is related to the isolation effect of the vegetation layer. The thermal isolation effect of the vegetation layer in natural ground usually origins from shielding of radiation and variably thermal properties. However, how well this mechanisms work beneath the embankment are not introduced in the study, which is essential to the conclusion. This point is a major comment. Please clarify.

Reply: Thank you. We are neglect to this problem. We add some explanation:

This is because the vegetation layer in an alpine meadow has thicker humus soils with a small thermal conductivity, reducing heat amount conduct down.

4. The terms of vegetation layer and alpine ecosystems are misused in the text, and the later is confusing when used for the layer beneath embankment. Please revise it.

Reply: Thank you. We read in detail the text, we revised misuse terms.

5. Line 130-133: Comparing to the secondary role of vegetation, the difference in embankment type should play a dominant role in influencing soil thermal regime. How do you distinguish the effect of vegetation layer with the primary factor? Add explanation as line 175-188.

Reply: Thank you. We add some explanation as following:

Under overlapping effect of climate change and engineering activities, soil

temperature upper the vegetation layer has an obvious deceasing trend, but soil temperature at the range of definite depth beneath the vegetation layer has an obvious rising trend for railway with the vegetation layer in alpine meadow (Fig. 8a, 8b and Table 4). However, soil temperature in all observation depth beneath show obvious rising trend for highway removing vegetation layer (Figure 8c, 8d and Table 4).

Technical Corrections:

1. Table 1 in P3: add space in “Altitude(m)”, and correct the altitude value for CMR2.

Reply: We revise into Altitude (m) and correct the altitude of 45.83 to 4583 in Table 1

2. Table 2 in P4: add sources for the values of climate conditions.

Reply: We add two references for the value of climate conditions, Zhao et al., 2004; Wu et al., 2012; Wu et al., 2015.

3. Line 76: “Figure 1” --> Fig. 1. Same problems in other places.
4. Line 88 and 90: “in situ” --> in-situ

Reply: We revised.

5. Line 88-91: one datalogger used at all sites? How simultaneously collect at different sites?

Reply: one or two data loggers used at every sites, for all sites, data are corrected at 10:00 a. m. Beijing Standard Time. We explain this problems in P5, Lines 90-91.

6. Line 109: “decrease” --> reduce
7. Line 111: “with average 3.54 cm/s” --> with an average of 3.54 cm/s. Same in other places. Line 110.

Reply: We revised.

8. Line 110-114: any comments for the different warming rates between alpine meadow and alpine steppe?

Reply: We add a sentence in Line 114.

The difference of mean ALT increasing rate between alpine meadow and alpine steppe is more than 2.0m/a.

9. Line 123-126. “This great difference in annual APT change rate between the QTH and QTR contributed to strong heat absorption by asphalt pavement ...” --> This great difference in annual APT change rate between the QTH and QTR is attributed to strong heat absorption by asphalt pavement ...”

Reply: Thank you. We revised.

10. Line 126: “Another contribution was engineering activity increase of interannual APT variation beneath embankments” --> not clear.

Reply: Thank you, this sentence seems to be repeated. We cancel it.

11. Table 4: “change rate of soil temperature beneath Embankment, °C/10a” --> Change rate of soil temperature beneath embankment, °C/10a.

Reply: We revised.

12. Figure 4 in P9: please detail the caption.

Reply: We revised into:

Figure 4 Soil temperature at 0.5 m depth beneath embankment, near artificial permafrost table and at 10 m depth.

13. Line 197: “Based on soil temperature data of nine monitoring sites over the period ...” --> Based on soil temperature observations at nine monitoring sites over the period ...

Reply: Thank you. We revised.

14. Line 203: “These findings indicate that alpine ecosystems can control APT magnitude beneath embankments but cannot control the rate of APT change” --> the controlling factor on APT magnitude is the alpine ecosystem? Why not climate or embankment?

Reply: Thank you. Except the effect of climate change and embankment on APT, Alpine ecosystem can influence APT magnitude beneath embankment but cannot affect the change rate of APT. So, we revised into:

These findings indicate that alpine ecosystems can influence APT magnitude beneath embankments but cannot affect the change rate of APT, except the effect of climate change and embankment.

15. Line 226: “Callaghan, T.V., Jonasson, S.: ...” --> Callaghan, T.V., and Jonasson, S.:. Similar error occurs in several references.

Reply: Thank you. We revised all references.

16. Line 255: “Li, R., ZHAO L.,...” --> Li, R., Zhao L.,...

Reply: We revised.

17. Please revise carefully the references as required style.

Reply: Thank you. We revised carefully the references as required style.

Reply comments on reviewer 2#:

The manuscript" Thermal impacts of engineering activities on permafrost in different alpine ecosystems in Qinghai-Tibet Plateau, China" presents measurements of the ground thermal regime in a range of settings impacted by construction activities. Although the manuscript contains a number of interesting data sets and findings, I do not recommend the manuscript for publication in TC, unless serious revisions are conducted by the authors. In particular, the authors present a number of interpretations for their measurements which are not well enough supported. This could be done by a) a statistical analysis of a sufficient number of samples (= boreholes in this case which is most likely difficult to achieve), or b) a careful, at least semi-quantitative argumentation involving the physics of the system, in particular the heat fluxes related to the thermal properties of the different parts/layers of the system and possibly the radiative forcing at the surface, or c) a study with a 2-dimensional ground thermal model considering the points raised under b).

Reply: We are very thankful for the comments of our manuscript and good suggestion. We try to add data measurement of three boreholes to further support our findings and we revise corresponding content in figures.

Major points:
The manuscript presents and discusses a lot of measurements in great detail (which is OK). However, some of the conclusions on the underlying processes, although not implausible, are not directly supported by the measurements. Although a number of boreholes exist, their number is too small for a statistical analysis that could secure the interpretations given by the authors. On the other hand, no data on the processes themselves are presented. In the following, I comment on the different results and conclusions as given in the abstract (l. 12 ff): "The results show that alpine meadows on the Qinghai–Tibet Plateau can have a controlling role within engineering construction effects on permafrost beneath embankments. "Why not also alpine steppes? Their controlling role would be different, but they would still have a controlling role?

Reply: When railway embankment constructed, the vegetation layer can be remained. The vegetation in alpine meadow can prevent heat conducting, because the vegetation layer in an alpine meadow in Qinghai-Tibet Plateau has thicker humus soils with a small thermal conductivity. Although a vegetation layer of alpine steppe were remained, there is not any humus soil with sparse vegetation. So, soil with sparse vegetation layer has pressed, heat insulation can be found. We adds some interpretation in discussion as follows:

This is because the vegetation layer in an alpine meadow has thicker humus soils with a small thermal conductivity, reducing heat amount conduct down.

“The artificial permafrost table (APT) beneath embankments is predominantly controlled by alpine ecosystems, : : :” Is this not a direct consequence of different ALTs before construction?

Reply: Thank you. It is my fault. I have not clearly show my mean. We revised as following:

As before railway constructed, the artificial permafrost table (APT) beneath embankments is not only affected by climate change and engineering activities, but controlled by alpine ecosystems. But, the change rate of APT is not closely related with those ecosystems, dominantly affected by climate change and engineering activities;

“: : : but the change rate of APT is not closely related with those ecosystems. “ Is it possible to draw this conclusion from the few boreholes, considering that the spatial variability could be quite high?

Reply: Thank you for your comments. We add some data measurement of four boreholes to explain this view. These data newly adding show the same result, seeing in Table 3.

“it is mainly related with cooling effects of railway ballast and heat absorption effects of asphalt pavement.” No evidence for this is presented, although it is a plausible conclusion.

Reply: Thank you for your comments. Except the effect of climate change, APT change is contributed to engineering activities. ALT in Qinghai-Tibet Plateau show a continuously increased trend, this result can be documented in many literature (Wu et al., 2012, The Cryosphere; Li, et al., 2012, Chinese Sciences Bulletin; Wu et al., 2015, Global and Planetary Change, listing in the reference). So, the trend of APT decreasing beneath railway embankment and increasing beneath highway can certainly contributed to the cooling effect of railway ballast and heat absorption heat of asphalt pavement because these data from general embankment without any measures of keeping cooling. So, this conclusion is plausible.

“Variation of soil temperature beneath embankments is independent of alpine ecosystems, but variation of mean annual soil temperature with depth is closely related to those ecosystems.” It is not clear to me what the authors mean with that and how this could be explained in terms of changing energy content of the soil.

Reply: Thank you for your comments. We may explain unclearly. Variation of soil temperature beneath embankment seems to be difficult to show the difference between alpine meadow and steppe, but we can easily see the difference of mean annual soil temperature with depth. So, we revised it as follows:

Variation of soil temperature beneath embankments is difficult to identify the difference between alpine meadow and alpine steppe, but variation of mean annual soil temperature with depth can be easily found out the difference between alpine meadow and steppe.

“The vegetation layer in alpine meadows can have an insulation role within engineering activity effects on permafrost beneath embankments. “ The problem is that the data set does not allow differentiating between the effects of road pavement/railroad grade vs. vegetation removal/no vegetation removal. It is at least possible that the described effects are entirely due to the different heat transfer processes in the roadbed and railroad grade.

Reply: Thank for your comments. We infer that the vegetation layer in alpine meadow can play an insulation role on underlying permafrost based on the mean annual soil temperature with depth. The data set cannot be differentiating this effect of road/railroad vs. vegetation, we need special research design to study this problems. On the different heat transfer processes in the roadbed and railroad grade, we simply explain that ballast pavement of railway has a strong air convection effect, it may have a cooling effects by many literatures, and asphalt pavement has a strong heat absorbed effect by many literatures. We specially study the physical mechanics of asphalt pavement by energy balance, but ballast pavement not. Except pavement has a difference with different heat transfer, the heat transfer of roadbed and railroad grade is same because filled soil is same.

“This insulation role is an advantage for alleviating permafrost temperature rise in the short term,” I agree with this finding, the around ten-year time series supports this. “but a disadvantage in the long term because of climate warming, suggesting that vegetation layer in alpine meadow should be removed upon initiating engineering construction” No evidence for this conclusion is presented.

Reply: Thank you for your comments. We cancel this conclusion.

-What happens to the insulating vegetation layer when it is buried under the railroad grade? How thick is this vegetation layer, and how would the heat transfer through this layer interact with the heat transfer through the railroad grade/road bed during different times of the year? How would lateral heat transfer play a role? Could the different geometries of the roadbed/the railroad grade play a role? Is it certain that winter snow cover can entirely be neglected in the discussion (the authors state that there is no steady or winter-long snow cover)? Is there snow accumulation at the shoulders of the road/railroad? What causes the significant offset between MAAT and MAGT (Table 2) if it is not snow? Is this related to radiative heating of the surface and thereby caused difference between MAAT and MAGST?

Reply: Thank you for your comments. You propose many problems being worth to study. Indeed, we cannot answer your problems now, because we may require special study design to study these problems. On the different geometries of the roadbed/the railroad grade, it have strong different heat effect of sunny-shadow slope, there are many papers to study this problems. In Qinghai-Tibet Plateau, no stable snow cover will accumulate at the shoulder of the road/railroad. MAGT is the temperature in the depth of 12 to 15 m beneath ground surface, heat transfer cause the offset between MAAT and MAGT. The offset between MAAT and AMGST is significant as the radiative heating of the surface.

Please revise the English language!

Reply: English language of our manuscript was revised by scientist of native English.

Minor point：
L. 32: How do you define alpine meadow and alpine steppe?

Reply: we define alpine meadow and steppe based on dominant species and vegetation cover.

L. 38: Please explain what is meant with “increasing permafrost table”?

Reply: L. 38, increasing of permafrost table means that permafrost table is deepening.

L. 54: How are the conclusions of the study influenced by the fact that the boreholes in alpine meadow are at the centerline of the QTR, but at the shoulder for alpine steppe?

Reply: Thank you for your comments. Because soil temperature at the centerline of the QTR has not been set from railway pavement to 20m for alpine steppe, we substitute soil temperature at the centerline of the QTR by using data from two shoulder of the QTR. This may have some heat effect of embankment slope, but it cannot change our understanding.

Fig. 1: What is meant by “Country” in the figure legends?

Reply: Sorry, it should be “country”.

l. 107: I don‘t understand this sentence. What is meant by “cool energy” and why should this be the case?

Reply: Thank you for your comments. “cool energy” means the amount of heat release in winter. So, we revised:

“cool energy” is revised into the amount of heat release.

l. 124: What is meant by “contributed”? Wouldn’t it rather be “caused by”?

Reply: Thank you. We revised “contributed” into “attributed to”

l. 126: What is meant exactly by “engineering activity increase of APT”?

Reply: Sorry, this sentence seems to be repeated. We cancel it.

l. 175: But this vegetation layer will decay and compress over time, thus changing its thermal properties? Is there any evidence how the “vegetation layer” under the railway looks today and how fast this process of decay/compression has occurred/is occurring?

Reply: Thank you for your comments. I absolutely agree with your opinion. From the view of Fig. 8, the temperature gradient from vegetation layer to a depth beneath embankment is gradually decreasing and trend of permafrost warming is gradually weakening, indicating the heat insulation effect of vegetation will decay. We add some explanation. At the same times, we revised the conclusions by adding the mentioned explanation. Thank you, you give us a right conclusion.

From the view of Fig. 8, the temperature gradient from vegetation layer to a depth beneath embankment is gradually decreasing and trend of permafrost warming is gradually weakening, indicating the heat insulation effect of vegetation will decay.

In abstract, we revise as following:

The vegetation layer in alpine meadow has an insulation role within the effects of engineering activities on permafrost beneath embankment, but insulation role is gradually disappeared because this vegetation layer will decay and compress over time. On the whole, this vegetation layer is an advantage for alleviating permafrost temperature rise in the short term, but this role is gradually weakened in the long-term.

l. 183: I don’t think that QTH and QTR are really comparable – one is a road, the other one a railroad grade, with completely different thermal properties. It is thus not necessarily clear that the described effect on ground temperatures is due to the vegetation layer.

Reply: Thank you for your comments. Although embankment pavement is different, filled soil of embankment is same,

l. 217: Why is it a disadvantage? I don’t think this follows from this study; at least no evidence for this is presented.

Reply: Thank you. According to your comments, we re-revise our conclusion. On the whole, vegetation layer is advantage.