

Development of New US Evaluation Course in Takasu Proving Ground

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ABSTRACT

An evaluation course was newly developed at the Takasu Proving Ground in Hokkaido to verify the compatibility of new type vehicles for the North American market with local road conditions. The driving states and ratio of occurrence on the evaluation route in the US were analyzed, and a course layout that aggregates sections with similar characteristics was created. The new course reduced the driving distance from 35 km to 16 km while maintaining the same driving feel. This shortened the driving time, from approximately 60 minutes for the evaluation route in the US, to 15 minutes. In addition, a paving method that uses a special jig to create surface undulation was devised, designing and constructing the undulating road surface with small amplitude as well as short wavelength needed to reproduce the ride comfort. This enabled to reproduce the body vibration that is an issue when driving in the US. These results realized a US evaluation course in the Takasu Proving Ground that enables verification of the driving feel unique to US road conditions in a short time.

1. Introduction

Honda opened its first test course in 1958, and then established the Tochigi Proving Ground (Tochigi PG) in 1979 to handle an increasing amount of function tests. In addition, the Takasu Proving Ground (Takasu PG) established in Hokkaido in 1990 gathered together the previously scattered cold weather test sites and expanded the range of vehicle safety and functionality that can be verified in a safe testing environment (Fig. 1).

The Tochigi PG contains courses such as an oval course for verifying the safety of vehicles driving at high speeds and a winding course for verifying handling performance under various conditions, from racing circuits to winding mountain roads. These courses help forge the structure of Honda vehicles and contribute to the development of Honda vehicles.

The Takasu PG contains courses that help meet the increasing demand for function tests at the Tochigi PG, and a high-speed oval course was established in 1995 to help safely confirm vehicle functionality during high-speed driving, such as on the German Autobahn. In addition, various test environments, such as an EU suburb course that simulates ordinary European suburban roads, have

been constructed since 2000 enabling evaluation of safety, functionality, and also vehicle performance in customer operating environments. These courses have been utilized to test Honda vehicles since the first-generation Fit.

Ongoing vehicle development has seen the development of simulation technology that aims to shorten development periods in the initial stages^{(1), (2)}. This has increased prediction accuracy for basic performances related to safety, stability, and comfort, which has reduced demands for additional courses.

However, demands are increasing for courses that enable evaluation of combined powertrain and handling performance, such as a cornering course that includes the ups and downs found on ordinary roads. In addition, control devices that enhance vehicle characteristics such as stability, responsiveness, and ride comfort, Advanced Driver Assistance Systems (ADAS), and devices for realizing autonomous drive are also being implemented in vehicles, so expectations are increasing for courses needed for verification of control systems.

When evaluating combined performances and vehicles that implement multiple advanced devices, the integrity of the completed vehicle and the passenger feel are key items. However, it is a challenge to perform all verifications using

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only the courses constructed so far.

In addition, there are many development models for North America and a high degree of maturation is demanded for each model, so verification on local roads takes much time.

Therefore, a new course was created in the Takasu PG that helps enable local testing of development models for North America to be performed in Japan. This report introduces this newly developed US evaluation course.

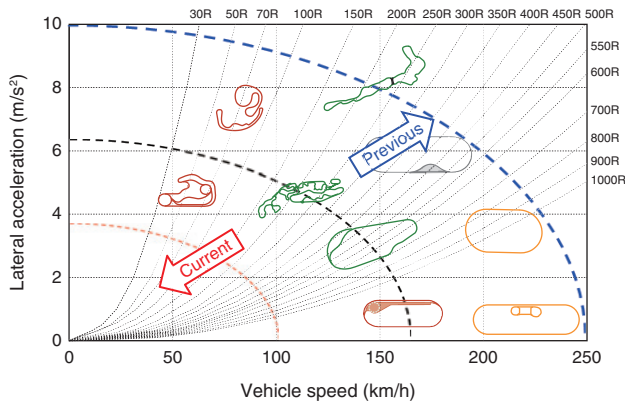


Fig. 1 Demand for test course development

2. Goals

A US evaluation course that achieves the following goals was newly established in the Takasu PG as a substitute for local tests of North American models.

- (1) A course layout that can be constructed within the PG site while reproducing the characteristics of the evaluation route in the US
- (2) A course that enables evaluation of combined performance and ride comfort, which are issues when driving in the US

3. Characteristics of Evaluation Route in US

Local verification of mass production models for the North American market is performed using a route starting from the Honda R&D Americas, Inc. in Los Angeles that is approximately 35 km long and takes around 60 minutes to drive. This route can be classified into four areas, City, Hill, Suburb, and Freeway, each with greatly differing characteristics.

The City area consists of a succession of straight road sections, except for intersections, and the vehicle speed is slow but frequent acceleration and deceleration are needed. The Hill area has curves with ups and downs and a small turning radius that needs to be driven at a faster speed than that in the City area. The Suburb area consists of straight road sections with many ups and downs that need to be

driven at a constant speed equal to that in the Hill area. The Freeway area has straight road sections and curves with no ups and downs, and a large turning radius that need to be driven at high speed.

Figure 2 shows typical views of these four areas.

Figure 3 shows an example of the change in vehicle speed when driving in the actual traffic flow.

Next, Fig. 4 shows the results of further dividing these classification areas into sections with similar characteristics and comparing the relationship between the turning radius and the road longitudinal slope in each section. In this figure, the circle size represents the distance of sections with the same characteristics, and the inverse of the turning radius is used so that straight road sections are zero. This figure quantitatively expresses the characteristics of the four areas described above, and the slope and turning radius were confirmed to vary greater in the Hill area compared



Fig. 2 Specific views of evaluation route in US

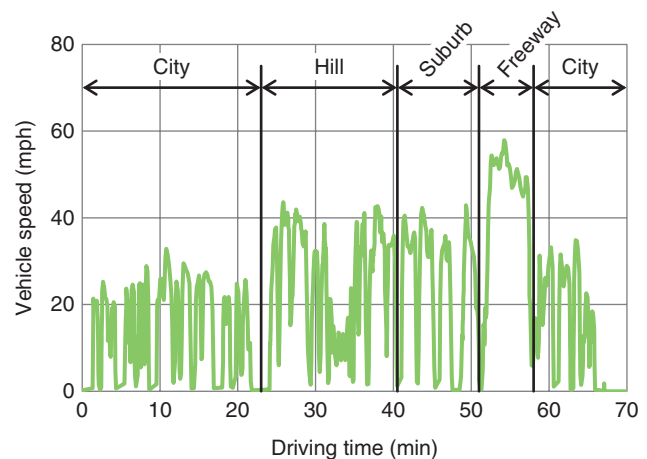


Fig. 3 Vehicle speed during evaluation route driving

to the City, Suburb, and Freeway area. This showed that it is necessary to reproduce a turning course with ups and downs to evaluate combined power train and handling performance.

Next, Fig. 5 shows an example of seat vibration, which is an issue for ride comfort, while driving the suburb area in the US.

Comparison of comments by development experts and measurement results revealed that reproduction of the vibration level in the frequency range from 10 Hz to 20 Hz is considered necessary to reproduce the ride comfort feel during the drive in suburb area.

Road surface undulation that affects ride comfort performance can generally be expressed by the wavelength in the direction of travel and the amplitude in the height direction as shown in Fig. 6.

The input frequency from the road surface to the tires varies depending on the vehicle speed. This makes it necessary to understand the vehicle speed and the body vibration level when determining the course road profile in order to reproduce the ride comfort vibration of the evaluation route in the US.

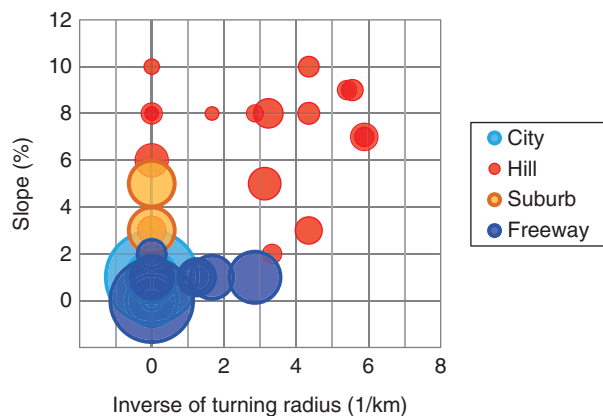


Fig. 4 Characteristics of each divided section of evaluation route in US

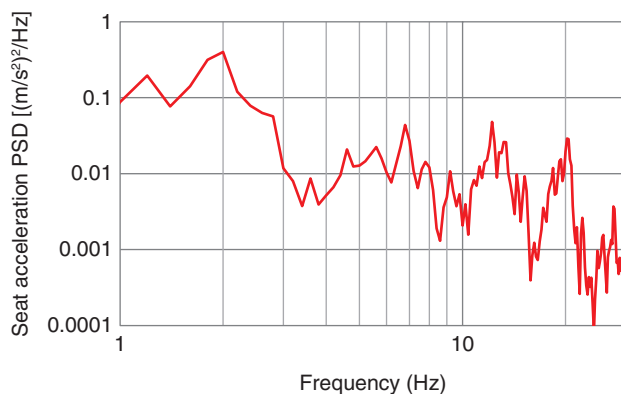


Fig. 5 Seat vibration during suburb area driving

Therefore, the road profile of the evaluation route in the US was measured to reproduce the ride comfort vibration that is an issue when driving in the US. Figure 7 shows the average wavelength and amplitude of the measured road surface for each of the four areas^{(3), (4)}. These results show that even when the road surface looks flat, such as in Fig. 2, each area of the US route has undulation with a shorter period and larger amplitude than that of a typical test course or a Japanese expressway.

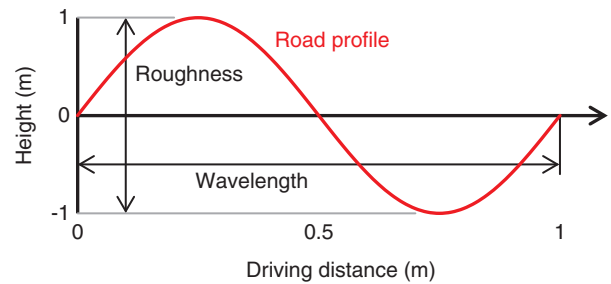


Fig. 6 Definition of pavement roughness

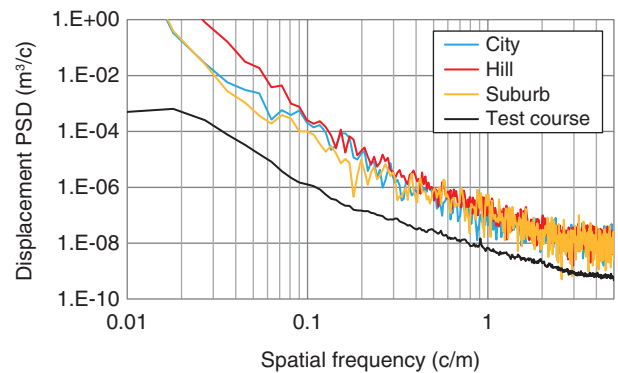


Fig. 7 Pavement roughness of evaluation route in US

4. New US Course Design

The new US course was laid out using part of the existing courses and some sloped land adjoining the Takasu PG (Fig. 8).

4.1. Planar Layout Design

The course design was based on the characteristics of the evaluation route in the US shown in Fig. 4. It was found that part of the existing high-speed oval course could be driven in place of the Freeway course. However, there were no existing courses corresponding to the City and Suburb areas, so these were newly created within the existing PG area. The existing PG area did not have an elevation difference like that of the evaluation route in the US, so some sloped land adjoining the existing site was newly developed to create the Hill course.

Figure 9 compares the Hill course characteristics of the evaluation route in the US and the PG course. This figure shows that in terms of the relationship between the turning radius and slope, the PG course reproduces characteristics resembling those of the evaluation route in the US.

In addition, the course layout enables to efficiently cruise through the City, Hill, Suburb, and Freeway courses while maintaining the same characteristics distribution ratio as that of the evaluation route in the US. This enabled to shorten the driving distance from 35 km for the evaluation route in the US to 16 km.

4.2. Road Profile Design

In order to reproduce the ride comfort of the evaluation route in the US, the road profile was designed while taking into account the difference in quality requirements when constructing ordinary roads and test courses^{(5), (6)}. Table 1 gives an overview of quality requirement standards for ordinary roads and test courses.

Figure 7 shows that the evaluation route in the US includes many undulation components with a wavelength



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Fig. 8 Candidate area for new US evaluation course

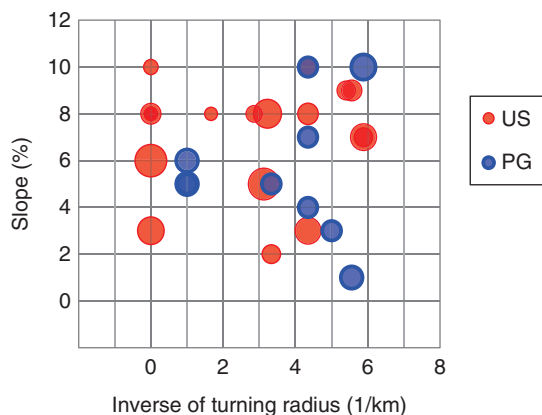


Fig. 9 Comparison of hill course characteristics

Table 1 Quality requirements for road construction

	Public road	Test course	
		High speed oval etc.	Ride road
Purpose	Driving safely for all cars under the law	Testing vehicles safely and stably at high speed	Evaluating vehicle vibration stably for a long period
Function	Stability, durability		
	Flatness	Flatness Surface strength Friction stability	Surface profile Wave length Amplitude
Quality requirement	Height, thickness, width, compaction density etc.		
	Flatness Friction	Flatness, Friction (High grade)	Road roughness Spatial frequency
Validation	Variance (± 2 mm)	—	Tolerance (± 1 mm)
Road structure	Surface course	Spread and leveled pavement made of asphalt mixture	
	Base course		
	Upper sub-base	Spread and leveled pavement made of asphalt mixture or crashed stone for mechanical stabilization	
	Lower sub-base	Spread and leveled structure made of crashed stone for mechanical stabilization	
	Anti-frost layer (Cold region)	Spread and leveled structure made of crashed stone	
	Subgrade	Leveled structure made of shaped soil	

around 1 m and an amplitude of ± 2 mm or less. However, the ordinary road standard allows an amplitude variance of approximately ± 2 mm as shown in Table 1, so it is a challenge to accurately reproduce the road surface shape of the evaluation route in the US.

4.3. Verification of Road Profile Design Values

The validity of the road surface amplitude to be used as the design value was verified by bench vibration tests to confirm the road surface wavelength and amplitude reproduction accuracy needed to reproduce the ride comfort vibration of the evaluation route in the US. Figure 10 shows the measured body vibration when driving on the evaluation route in the US, the results when vibrated using the road profile obtained by measurement, and the results with the vibration level corrected.

These results show that when reproducing the body vibration of the evaluation route in the US, it is necessary to accurately reproduce the amplitude to within ± 1 mm, which is smaller than the road surface amplitude obtained

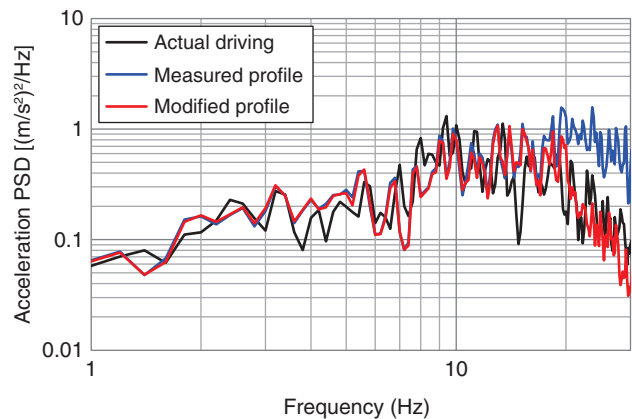


Fig. 10 Road profile correction by 4 poster testing

by surveying, in order to reproduce ride comfort vibration of 10 Hz or more.

5. Reproduction of Undulation with Short Wavelength and Small Amplitude

As described above, it is a challenge to accurately create undulation with the wavelength around 1 m and an amplitude of ± 1 mm needed to reproduce ride comfort using road construction methods for ordinary roads that emphasize flatness. Therefore, a method called three-dimensional paving was devised and applied to accurately reproduce the intended wavelength of around 1 m and an amplitude of ± 1 mm. This method consists of driving an asphalt finisher along guides on guide rails with a wavy shape in the normal surface paving method that emphasizes flatness (Fig. 11).

This method enabled accurate reproduction of the short wavelength and road surface amplitude design values needed to reproduce ride comfort as shown in Fig. 12.



Fig. 11 Proposed surface paving method

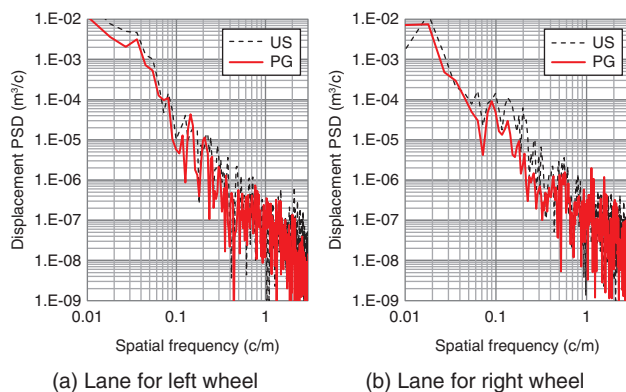


Fig. 12 Comparison of pavement roughness of suburb course

6. Verification Results

Figure 13 shows an overview of the completed new US course. From the starting point, the course enters a City course newly developed on the inside of the high-speed oval course. After finishing the City course, the newly developed Hill course can be accessed via a connecting road through a tunnel under the high-speed oval course, as indicated by the arrow in the figure. The Hill course is entered from the middle and forms a route with U-turns at both ends. The Suburb course newly developed on the outside of the high-speed oval course can then be accessed from the Hill course via a connecting road, and a new entry lane has been made enabling entrance to the high-speed oval course used as the Freeway course from the Suburb course while maintaining the vehicle speed.

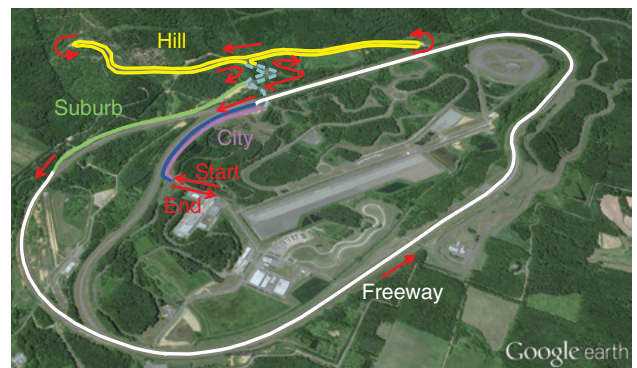
This new US course enables vehicles to drive through the four areas shown in Fig. 2 in the same order as the evaluation route in the US shown in Fig. 3. However, the overall distance is shortened from approximately 35 km from the route in the US to 16 km, and the acceleration, deceleration, and stopping ratios of occurrence are also reduced. This enabled to shorten the driving time from approximately 60 minutes for the evaluation route in the US to 15 minutes.

The driving results for the evaluation route in the US and the newly established evaluation course were compared to verify the reproducibility of the US road driving feel.

Figure 14 shows the relationship between the lateral acceleration and the yaw rate while driving. As shown in this figure, the relationship between the lateral acceleration and the yaw rate while driving on the new US evaluation course exhibits the same slope as that for the evaluation route in the US, which confirmed that the planar layout of the test course has the same characteristics as those of the evaluation route in the US.

Figure 15 compares the seat vertical vibration during Suburb driving, which is an issue for the ride comfort feel.

This figure shows that the vertical vibration level while driving on the new US Suburb course matches that for the



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Fig. 13 Overview of new US evaluation course

evaluation route in the US in the target frequency range of 10 Hz to 20 Hz. This confirmed that the test course road profile reproduces the ride comfort feel characteristics of the evaluation route in the US.

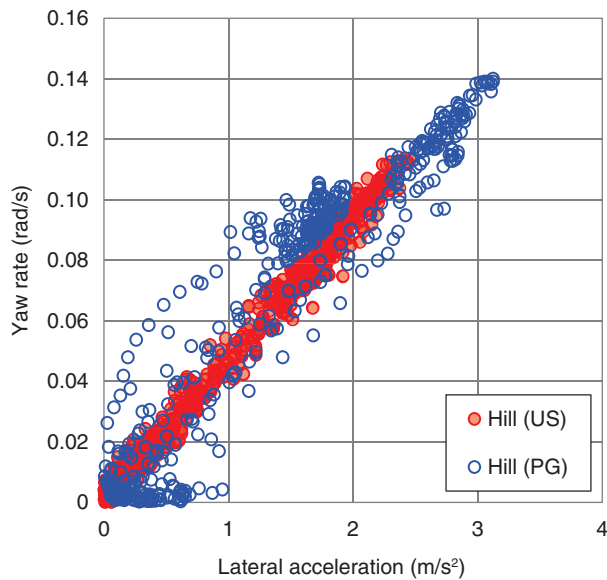


Fig. 14 Comparison of lateral acceleration and yaw rate

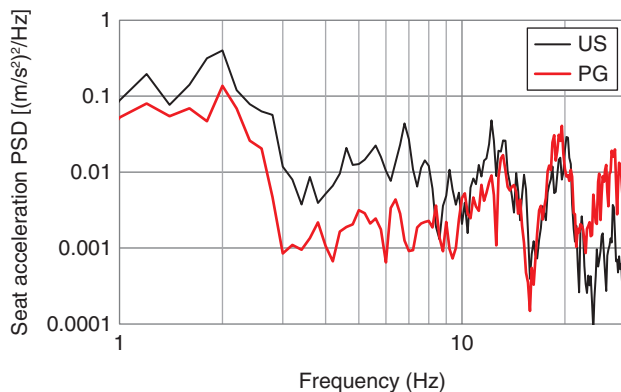


Fig. 15 Comparison of seat vibration during suburb course driving

7. Conclusion

A new US evaluation course was developed in the Takasu PG that enables performance of the same verification as local tests of North American models, and in a shorter time than when using the evaluation route in the US.

- (1) The course layout could be constructed within the PG site by shortening the length from 35 km for the evaluation route in the US to 16 km while maintaining the same characteristics distribution ratio as that of the evaluation route in the US for each of four areas. This enabled to

shorten the driving time from approximately 60 minutes for the evaluation route in the US to 15 minutes.

- (2) The characteristics of the evaluation route in the US were reproduced in the relationship between the turning radius and the longitudinal slope, enabling evaluation of combined performance. In addition, a course surface paving method was devised to construct the target road surface undulation with a wavelength of 1 m and amplitude of ± 1 mm, enabling evaluation of ride comfort.

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