

## APPLICATION OF ADVANCED MEASUREMENT TECHNOLOGY IN EVALUATING ROAD SURFACE QUALITY IN VIETNAM

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**Abstract:** Road roughness and surface texture are very important factors, which influence both ride quality and vehicle operating costs. This paper showed the result of RITST on using advanced measurement technologies in checking and evaluating the road surface quality in Vietnam.

**Key Words:** Road roughness, Road surface texture, IRI

### 1. ROAD SURFACE CHARACTERISTIC

There are two important factors of road surface, which influences the ride quality. They are:

#### 1.1 Road roughness

Road roughness can be defined as the deviation of pavement surface from a true planar surface with characteristic dimension that affects vehicle dynamics, ride quality, dynamic loads, and drainage. Road roughness is thus the key variable linking user costs to the road face condition. It is an important yardstick both for pavement condition and vehicle operating costs.

#### 2.2 Road surface texture

Road surface texture and resistance to wet road skidding are important factors influencing the safety of drivers and passengers, the quality of goods and the speed of vehicles. The surface texture strongly affects the skid resistance of a road.

### 2. MEASUREMENT TECHNIQUES IN THE WORLD

#### 2.1. Roughness Measuring System

Although many different types of road roughness measuring exist, they all can be classed into two main groups.

### The first group- Profilometric system

Consisting of systems, that can measure the profile of road or based on their measurement system, the profile of road can be measured indirectly as well. This group can be again subdivided into 2 groups.

- The 1a: Consisting of systems that measure the true profile of the road at acceptable sampling intervals. The accuracy of these measurements is extremely high. Some specialized types of device in this group are TRL Profile Beam (UK), Dipstick (USA). The devices of this group can be used to calibrate other methods of measuring road roughness.
- The 1b: Consisting of systems that measure the road profile over a moving datum and therefore capture the road profile over limited waveform at high speeds. Instruments of this type are the TRL high-speed profilometer, the APL trailer... and particular the Laser Profiler, the automated road profiling system, which measure the pavement surface at vehicle speeds up to 100 km/h.

### The second group- Response type road roughness measuring system ( RTRRMS)

The system consists of a suitable vehicle with instrument mounted on rear axle or trailer axle to measure the movement of a suspension system in response basically to the unevenness of the road surface, which the vehicle travels on. Some specialized versions of the RTRRMS are Mays Ride Meter (USA), TRRL Bump Integrator Unit (UK)...

The dynamic properties of these vehicles or trailers are unique for each system and they also tend to change with time. Thus the "raw" measures of roughness obtained from RTRRMS system must be "corrected" by calibration and de-scaled comparison with any other similarly calibrated measure of roughness by using the device of first group as TRL Profile Beam (UK), Dipstick (USA), Laser profiler...

The problem was, roughness data from different part of the world could not be compared because the measures were based on different methods and hardware.

In 1982, the World Bank initiated a correlation experiment in Brazil to establish correlation and calibration standard for roughness measurement and published to define a reference measure that was call the International Roughness Index (IRI). The advantage of IRI is:

- IRI is a time-stable.
- IRI can be measured with any valid profiler.
- IRI measure from different countries is large compatible.

The unit of IRI is m/km, the ranges is from 0 to 20 represented by different classes of road.

## **2.2. Surface Texture and Resistance Skidding Measuring System**

They all can be classed into two main groups.

Group 1: Measurement of surface texture. There are a lot of methods using to measure the surface texture, they are:

- Sand Patch method;
- Stereophotografic analysis methods;
- Texture measurement method using a laser based on non-contact high transducer.



Group 2: Measurement of skidding resistance. A great variety of test vehicles has been designed for the measurement of the skidding resistance between tyre and road surface, in which there are four major methods have been used widely in the world. They are:

- The sideway-force test: SCRIM (Side way-force Coefficient Routine Investigation Machine).
- The braking-force test: Grip Tester.
- Passenger-car braking test.
- The portable skid-resistance tester.

### 3. MEASUREMENT TECHNIQUES IN VIETNAM

#### 3.1. IRI Roughness Measuring

The first time in April 1986 pavement roughness measurements have been carried out by RITST for rehabilitation design for the section of the National Highway No.1 from Saigon to Can tho (150 km two-lane section) with 2 instruments:

- Profilometric system: Dipstick-DS 2000 (USA).
- Response type road roughness measuring system: Mays Ride Meter ( USA ).

The procedure for roughness measurements followed ASTM E1082 Standard, TRRL Research Report 301, operating instructions of Dipstick and Mays Ride Meter with 4 steps:

Step 1: Check calibration the devices

Step 2: IRI Calibration through correlation

- Selecting calibration sections
- Selecting the roughness survey velocity
- Profiling with Dipstick and calculating IRI on calibration sections
- Running Mays Ride Meter on calibration sections
- Calculated IRI equation from correlation

Step 3: Roughness measurements on project section

Step 4: Report

Calibration of the bump integrator was carried out by use of a Dipstick Road Profiler DS2000, which measure the true profile using a laptop computer and a Road Face Data Collection Program to collect the data and calculate the International Roughness Index IRI of the road at calibration section. A total of four calibration sections were located at the project road.

Roughness survey have been carried out by use of a vehicle ( Hyundai ) trailed Mays Ride Meter on the two-lane project road.

Using calibration equation to estimate the IRI at 100-m intervals on each lane. The value of the estimate IRI ( m/km ) on each lane, the average IRI of two lane at 100 m intervals and the average IRI of sub-sections are reported.

The results of IRI on 100 m intervals derived from roughness survey showed clearly the state of road and location of deterioration.

Based on experiment gained from Roughness measurements on Sai gon-Can tho project section, RITST carried out roughness survey on some project roads: Dong Ha-Quang Ngai (200 km) on July 1997, Vinh-Dong Ha ( 300 km ) on March 1998. The procedure for roughness measurements followed as above, but the response type road roughness measuring system using TRL Bump Integrator Unit (UK) with the " Road Measurement Data Acquisition System" ROMDAS was installed.

In accordance with requirement from State Committee for Assessment of the Highway construction quality, roughness test was carried out on Highway No.5 (four-lane section of 98 km) in April 1999, on Highway No.1 (two-lane Phu ly-Vinh section of 66 km ) in August 1999. The equipment used in testing were TRL Profile Beam ( UK ) and TRL Bump Integrator Unit.

Since 1999 RITST has been using the 2RT Laser Profiler from Australia Road Research ARRB to measurement surface roughness in Vietnam. The ARRB 2RT Laser Profiler system is a laser based instrumentation system mounted on a vehicle. The system acquires the appropriate data needed to measure the pavement surface profile in each wheel path at vehicle speed in range from 30 km/h to 120 km/h. The profile is subsequently analyzed via the Quarter Car model to calculate the International Roughness Index-IRI.

Over view of the ARRB 2RT Laser Profiler can be seen at picture 1.



Picture 1. ARRB-2RT Laser Profile

Considering the success achieved using this method, the 2RT Laser Profiler was performed in September 1999 by repeated IRI measurement in 1km two lane trial section at Highway No.1, whose IRI value had been known already before. Measurements with the Hyundai mounted laser beam need to be repeated 5 times on calibration section with 5 speeds. The IRI results of 5 times running at trial section can be seen at table 1.



Table 1. IRI Results

Chainage	IRI ( m/km )				
	Run 1	Run 2	Run 3	Run 4	Run 5
Km 241 + 0	V = 80 Km/h	V = 70 Km/h	V = 60 Km/h	V = 50 Km/h	V = 40 Km/h
Km 241 + 100	2.51	2.42	2.47	2.45	2.46
Km 241 + 200	2.58	2.53	2.49	2.53	2.59
Km 241 + 300	2.07	2.02	2.09	1.97	1.97
Km 241 + 400	2.27	2.18	2.23	2.25	2.14
Km 241 + 500	2.39	2.45	2.44	2.38	2.42
Km 241 + 600	2.29	2.42	2.45	2.43	2.43
Km 241 + 700	1.96	2.08	2.10	2.06	2.13
Km 241 + 800	1.85	1.99	1.87	1.93	1.94
Km 241 + 900	2.50	2.47	2.53	2.53	2.52
Km 242 + 0	1.57	1.62	1.72	1.77	1.75
Average IRI on 1 km section	<b>2.20</b>	<b>2.22</b>	<b>2.24</b>	<b>2.23</b>	<b>2.24</b>

Results from trial tests show that The ARRB "2RT Laser Profiler" is independent speed system in IRI roughness measurement.

In accordance to requirements from State Committee for Assessment of the Highway construction quality, RITST carried out roughness and surface texture tests by using " 2RT Laser Profiler" on Highway No.1, R100 project of 100 km in September 1999, R300 project of 160 km in October 1999, Saigon-Cantho project of 150 Km in July 2000, on Highway No.5 and contract Package No 3 of 50 Km in January 2001.

The results of IRI roughness on some road sections in Vietnam can be seen at table 2.

Table 2. Results of IRI roughness on some road sections

No	Road Section	IRI (m/km)	Road condition	Test time
1	BTL-NB Highway, Km4 - Km7	2.3	New road section	4/1997
2	NTL Road 5 km section	2.4	New road section	4/1997
3	Lang Road, 4 km section	3.7	5 years paved road	4/1997
4	<u>Highway No.32</u> Caugiay section Km38-Km39	2.3 8.4	New road section Old road section	4/1997
5	<u>Highway No.6</u> Km9-Km10 Km19-Km20 Km21-Km22	1.8 4.9 9.8	New road section Old road section Deterioration section	4/1997

6	Highway No.21A Km20-Km21 Km18-Km19 Km37-Km38	2.0 4.4 5.9	New road section Old road section Poor road section	4/1997
7	Highway No.70	8.7	Deterioration section	4/1997
8	Highway No.3, Km10-Km12	2.6	Old road section.	4/1997
9	Highway No.1, 150 km Saigon-Can Tho section	2.5-4.5	Old road section. (prepare for rehabilitation construction )	4/1996
10	Highway No.1, 200 Km Dong ha-Quang ngai section	2.5-7.8	Old road section. (prepare for rehabilitation construction )	7/1997
11	Highway No.1, 300 Km Vinh-Dong ha section	2.7-8.2	Old road section. (prepare for rehabilitation construction )	3/1998
12	Highway No.5, 78 Km	1.5-2.0	New construction section	4/1999
13	Highway No.1, 66 Km Phu ly-Vinh section	1.7-2.8	New rehabilitation section	8/1999
14	Highway No.1, 110 Km R100 section	1.7-3.4	New rehabilitation section	9/1999
15	Highway No.1, 160 Km R300 section	1.6-3.2	New rehabilitation section	10/1999
16	Highway No.1, 150 Km Saigon-Can Tho section	1.8-2.9	New rehabilitation section	7/2000
17	Highway No.5, 50 Km section	1.6-2.5	New construction section	1/2001

Although the traffic volume in these road project is very high, roughness and surface texture tests by using " 2RT Laser Profiler" is quickly and convenient ( test time at 2 lane section of 160 km is only 1 day ).

### 3.2. About Surface Texture

Since 1996 RITST has carried out surface texture tests using "sand cycle" method to assess the surface quality of road network in Vietnam.

In 1999, RITST used The 2RT Laser Profiler to measure the texture in the form of Sensor Measure Texture Depth. Texture is measured continuously in each wheel path along the entire pavement surface using a non-contact laser transducer. It can be correlated with manual measure texture as Sand Patch texture depth by using regression equation from calibration sections.

The correlation procedure of sensor measured texture depth to mean texture depth (from Sand Circle) is as follow:

Five test sites were selected, ten meter in length. A guideline was marked on the pavement surface to ensure that when running the texture laser cameras were positioned in both the inner and outer wheel paths. A foam marker was placed in the path of the outer laser to accurately identify the start of the test section. Three separate passes were made and an average obtained for each segment.



Sand cycle tests were performed along the inner and outer wheel paths of test section following the same measurement path as the texture lasers. The sand circles were measured at 562-mm centers.

The value of two test methods of six tests sites shown in table 3.

Table 3. The value of two test methods in 6 sites

Test site	Site 1		Site 2		Site 3		Site 4		Site 5	
	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner
Average mean texture depth	0.32	0.36	1.14	1.09	0.83	0.77	0.42	0.43	0.23	0.19
Average sensor measured texture depth	0.44	0.43	1.08	0.85	0.63	0.66	0.47	0.45	0.38	0.42

The average sensor measured texture depth from 2RT laser were plotted against the average mean texture depth by sand patch method. A regression analysis performed on this data revealed an excellent correlation coefficient of  $R=0.94$  is:

$$N=0.6148*T+0.025$$

Where: N, average mean texture depth by sand patch method ( mm );

T, average sensor measured texture depth from "2RT Laser Profiler".

Results of macro texture measurements by sand patch method on typical paved road sections in Vietnam can be seen at table 4.

Table 4. Results of macro texture measurement

No	Road section	Mean texture depth, mm	Road condition	Test time
1	BTL-NB highway, asphalt concrete, fine aggregate	0.25	Recently paved road	1/1996
2	BTL-NB highway, 500 m VTO improved skid resistance technology section.	0.87	One year paved road	1/1996
3	BTL-NB highway, 500 m DM improved drainage technology section.	1.11	One year paved road	1/1996
4	Road No. 32	0.33	Two months paved road	1/1996
5	NTL Road	0.40	5 years paved road	1/1996

6	BTL-NB highway, old section	0.37	5 years paved road	1/1996
7	Highway No.3, Dong Anh section	0.17	Old paved road	1/1996
8	Highway No.1, Phap Van section	0.17	Old paved road	1/1996
9	Highway No.5, Trau Quy section	0.17	Old paved road	1/1996
10	Nguyen Trai Road, Km 9- Km 10 section	0.19	Old paved road	1/1996
11	Highway No.5, 78 km section	0.45-0.50	New construction section	4/1999
12	Highway No.1, 110 km R100 section	0.45-0.52	New rehabilitation section	9/1999
13	Highway No.1, 160km R100 section	0.44-0.53	New rehabilitation section	10/1999
14	Highway No.1, 150 Km Saigon-Cantho section	0.42-0.52	New rehabilitation section	7/2000
15	Highway No.5, 50 Km section	0.45-0.54	New construction section	1/2001

## 4. CONCLUSIONS

### 4.1. About Surface Road Roughness

From the IRI roughness results on the roads (detailed at table.1), some remarks and conclusions could be resumed:

- Road quality is represented through the result of IRI roughness test.
- Environmental factor, material quality, construction quality effect the IRI.
- Serviceability time, traffic volume, axle-loading factors relate closely with the IRI.
- With new asphalt construction section in Vietnam, the IRI may be gained 2 if construction procedure obeyed as Technical Specification.
- When the value of  $IRI \geq 8$ , paved road whole surface is damage, need to be reconstructed.
- The road surface roughness (IRI) is estimated and predicted as the sum of components: structural deformation related to roughness, equivalent standard load flow, surface condition, age-environment- related roughness term.



#### 4.2. About Road Surface Macro Texture

From the surface macro texture results on the roads (detailed at table.3), some remarks and conclusions could be resumed:

- In general, surface texture in roads of Vietnam is low (average H is from 0,2 to 0,5 mm ). It is not enough safety for high-speed traffic.
- The two test sections using technology of Very Thin Overlay-VTO and Drainage Mix-DM with mean texture depth higher than 0.8 mm permit the vehicles running at high speed (  $V \geq 120$  km/h ).

#### V. RECOMENDATIONS

1. It is necessary to research in details and publish soon the Standard Test Method for Roughness test (by IRI), the Standard for assessment of the road condition from roughness test in Vietnam.
2. It is necessary to research in details and publish soon the Standard for assessment of the surface road texture in Vietnam.
3. The ARRB "2RT Laser Profiler" system is very convenient in surface texture and roughness survey in Vietnam.
4. Need to be application advance technology to improvement the skidding resistance of road surface in Vietnam.

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