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INSPECTION OF EASTERN HARBOUR TUNNEL

1. General Scope of Work

The intent of this report was to inspect the asphalt pavement of the Eastern Harbour Tunnel and evaluate the application of RJSeal™ at the Number 14 Toll Booth on Kowloon side, the Kowloon Entrance area, the Immersed Tube Tunnel and the South-End at Quarry Bay.

2. General Conditions of the Asphalt Road Surface

The Eastern Harbour Tunnel is operated by the New Hong Kong Tunnel Company Limited (NHKTC). Figure 1 (including 1a to 1f) shows the general location. The records of NHKTC indicates a high traffic volume passing thru the tunnel, which is estimated at more than 80,000 vehicles per day.

2.1 Auto Toll Booth Number 14

Figure 2 (including 2a to 2d) illustrates the location of two demo strips that were undertaken in proximity to Toll Booth Number 14, located at the Kowloon side of the facility. This toll booth is unmanned and serves as an automatic toll collector for heavy vehicles, such as buses and trucks which travel to Hong Kong Island. Immediately in front of the toll booth, a 15-metre long strip (2 metre wide) was treated with RJSeal™ on March 5, 2004 for demonstration purposes. Similarly a 15-metre long demo strip was completed immediately after the concrete apron beside Toll Booth No 14.

The asphalt pavement at this location is a Stone Matrix Asphalt (SMA) with 25 mm aggregate at the tollbooth. Normally the pavement fails quite quickly in proximity to the tollbooths and is completely replaced every 6 to 9 months, due to the excessive traffic of heavily loaded vehicles. This is attributable to the fact, that all vehicles usually would slow down or brake in front of the Auto Toll Booth and then resume their speed, thus adding dynamic loading to the heavy static load of these vehicles, resulting in short life span of the asphalt road at about 6 to maximum 9 months. After more than 6 months, the site observation and experience with these two demo strips shows that RJSeal™ has extended the life of the asphalt pavement and still shows no significant sign of fatigue, whilst on the other side of the road surface where no RJSeal was applied, cracks are evident.

2.2 Entrance Area

The entrance to the tunnel descends at a gradient of approximately 6% and this portion had extensive problems, with water ingress from sidewalls and floor. See Figure 3 for a graphic illustration of water ingress, through a porous area in the floor. Shortly after the opening of the Eastern Harbour Tunnel for service, the operating company had to install supplemental drainage down the centre of the tube (between the two driving lanes) with branch lines to the side of the tube for collection of nuisance water.

Furthermore, water percolating down the exterior skin of the tube and then arising at porous portions of the asphalt overlay results in erosion of the bitumen binder and eventually leads to the formation of honeycomb asphalt and thence potholes and local failure of the asphalt pavement. These potholes are cut out and patched on a periodic basis.

The drainage system that was retrofitted, post-completion also has presented some maintenance problems due to flexure of the asphalt pavement that overlies the cross drains from the central collector. See Figure 4 for illustration of the asphalt failure at the cross drain. This is especially prominent in the initial portion of the tunnel at the decline on the way down to the level central portion. Inspection of the asphalt pavement in the central portion shows no significant problems, although in the wheel path of both lanes, there is a raveling (loss of fines and exposure of the stone matrix).

See Figure 5 illustrating the exposure of the stone matrix. At the present time, the exposed stones have sufficient bitumen binder to hold them in place, but it is suspected that in the next year, some maintenance material should be applied to rejuvenate the bitumen, which is now quite stiff. Attempts to dig into asphalt pavement with a pocketknife indicate that the bitumen binder is now quite inflexible.

2.3 Immersed Tube Portion

The two-lane, southbound tube of the tunnel was inspected, which at the time was closed to vehicular traffic, as various maintenance activities were underway. In the immersed tube portion of the Eastern Harbour Tunnel, the asphalt pavement is the original pavement dating from completion of the tunnel in 1987/88. An SMA pavement, with 10 millimetre-sized stone was used in the tunnel.

The appearance of the majority of the asphalt pavement in the central portion of the immersed tube suggest that some preventive maintenance measures will be required within the next year, to ensure that it continues to provide trouble-free service.

2.4 South-End at Quarry Bay

At the Quarry Bay end of the tunnel, in immediate proximity, where the spiral exit ramp is located, inspection of the porous frictional course (PFC) asphalt pavement material showed that several areas had been repaved. Some segments were three years old and current maintenance plans called for milling and repaving shortly. Adjoining areas had asphalt pavement that was two years old which appeared to have a raveling problem (loss of fines had occurred). Some portions were only one year old and still looked remarkably functional. Given the current experience and high traffic volumes in the southbound tube, the asphalt road probably would not last more than three years.

Given the current plans to replace the three year old pavement at the Quarry Bay exit, which has raveling problems in the wheel path, especially on the outside portion of the exit ramp (with some coarse material loss), an experiment was proposed whereby RJSeal™ would be applied to the one, two and three year old asphalt pavement. This experiment was carried out on 30 September 2004, due to the qualified success of the demonstration of RJSeal™ in May 2004, adjacent to Toll Booth No. 14.

3. Test Methods

The following test procedures were implemented to test the asphalt pavement. Figure 6 shows the suggested type of equipment that can be used for the various test procedures. Comparisons were undertaken at several locations on both the untreated and RJSeal™ treated sections (see Figure 7).

3.1 Macrotexture Depth

The sand patch test (ASTM Standard E965-96 OR China Standard T 0961-95) was used to ascertain the Pavement Macrotexture Depth. It reflects the roughness of the surface. By comparisons, it would show that the RJSeal application should not affect the macrotexture depth.

3.2 Water Penetration

Water Penetration Tests (China Testing Standard T 0730-2000) were undertaken at several locations on the untreated portion of the road, in close proximity to the test strips and later on the RJSeal™ treated section. For porous friction coarse, the water should flow through before and after the RJSeal treatment.

3.3 Hydroplaning Potential

An "Outflow Meter" manufactured in the U.S.A. by Humble Equipment Company of Ruston, Louisiana and sold under the trademark "Outflow Meter" was used to measure and compare the relativity of the asphalt pavement's macrotexture to ascertain the hydroplaning potential on the RJSeal™ treated surface, versus the untreated surface. The procedure is documented in the ASTM working paper, WK-364. The Outflow Meter gives readings in seconds for the dissipation of a known quantity of water. It is suggested that any readings between 3 and 10 seconds are excellent and readings less than 15 seconds are satisfactory for an asphalt pavement surface, if hydroplaning is to be minimized.

These aforesaid tests are not damaging to the pavement as they don't require core samples to be taken, which could create potential trouble spots for pavement maintenance. The asphalt pavement can be monitored and allow comparison between the RJSeal treated asphalt pavement and the untreated pavement.

4. Test Results

4.1 Auto Toll Booth Number 14

There is no better test of a product than the reality of its application. The two test patches before and after the Auto Tollbooth were put into service in March and for more than six month, under non-stop daily service under the severe weather of the rainy season in this semi-tropical place from March till September. The traffic records indicate that more than 1.2 million vehicles passed through the Auto Tollbooth alone during the 6 month period ending September 5, 2004. This included 25,000 heavy goods vehicles, 64,000 single-decker buses and 300,000 double-decker buses.

The untreated road surface showed cracks and signs of structural failure. It has to be replaced. Yet when the author went to the site in September and again in early November, the treated surface still showed no sign of fatigue or failure and raveling was negligible, as no fine loss was observed. The test proves that it can withstand the static load and induced live load of the vehicles whilst braking and accelerating.

4.2 South End at Quarry Bay (porous friction coarse surface)

Location			
1 year Old Surface	**Untreated Surface**	**Treated Surface**	**Remarks**
• Macrotexture Depth	0.93 mm	0.93 mm	Test Nos. 13-16
• Water penetration	100 ml/min	685 ml/min	Test Nos. 13-16
• Hydroplaning potential	4 seconds	4seconds	Test Nos. 13-16
2 year Old Surface	**Untreated Surface**	**Treated Surface**	**Remarks**
• Macrotexture Depth	0.98-1.24 mm	1.04-1.24 mm	Test Nos. 1-12
• Water penetration	480 ml/min	160-960 ml/min	Test Nos. 1,3,4,6
• Hydroplaning potential	4 seconds	3 seconds	Test Nos. 7,10
3 year Old Surface	**Untreated Surface**	**Treated Surface**	**Remarks**
• Macrotexture Depth	0.42-0.48 mm	0.41-0.47 mm	Test Nos. 7,10
• Water penetration	135 ml/min	135 ml/min	Test Nos. 7,10
• Hydroplaning potential	2 seconds	2 seconds	Test Nos. 7,10

5. Conclusion and Recommendations

The tests show that the applications of RJSeal will not alter the macrotexture of the asphalt surface, which is closely related to the surface friction.

For general asphalt road surface, it helps seal the surface to prevent water damage to the substructures by rejuvenating the old asphalt. Since RJSeal tackles only bitumen and not fill in the space like crack sealant, the tests prove that RJSeal does not affect the water permeability of the porous friction coarse (PFC). In fact, in some cases, it helps improve the water permeability.

The hydroplaning potential tests handle the relativity of the macrotexture and the surface friction of the RJSeal treated surface versus the untreated surface. All the tests shows no changes, thus proving that the RJSeal would not alter, either increase nor decrease the surface friction of the asphalt road surface.

The tests also prove that the road can be opened to traffic four hours after the RJSeal application.

5.1 Toll Booth Area

The demonstration proves that RJSeal can stabilize the new asphalt and in fact improve the resistance to flexure cracking due to the high volume of traffic with heavily loaded vehicles, whilst not losing its ductility.

The phenomena suggest that the life span of asphalt road surface of the toll booth area can definitely be extended through the application of RJSeal.

Since there is no extensive data to identify how long the life span can be extended, the test result does suggest that RJSeal should be applied at the toll booth area at least once every 6 months. As such, it is believed that the life span of the road surface can last at least two to three more cycles, say 18 months.

5.2 Entrance Area

The general inspection of the entire Kowloon side toll area including the entrance area also suggests that some preventive measures must be undertaken in the near future to prevent further serious road surface deterioration of the structures.

5.3 Immersed Tube Portion

The general inspection indicates that the road surface condition is still acceptable. However, hairline cracks can still be spotted and fine loss occurs. It was informed that the asphalt pavement is still the original pavement dating from completion of the tunnel in 1987/88.

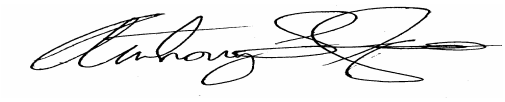
The appearance of the majority of the asphalt pavement in the central portion of the immersed tube suggests that some preventive maintenance measures will be required within the next year to ensure that it continues to provide trouble-free service. The author prefers a well-planned preventive maintenance to ensure no emergency maintenance

5.4 South-End at Quarry Bay

Porous friction coarse is a type of asphalt pavement that is very open to conduct water away from the surface and provide a surface with superior skid resistance. The tests prove that RJSeal would improve the performance of PFC.

The asphalt sections in this area appear to last around three years. It is not suggested to apply RJSeal to the three-year-old section, as by that time it has deteriated and has to be repaved. However the application of RJSeal once every year on a two year old asphalt surface should extend the life span of the road surface. Based on the trial experience, it should extend the life of the PFC, some two to three years.

Sincerely



Anthony G. Speed, P.Eng. (Ontario and New Brunswick, Canada)

Enclosures: Figures 1 (1a-1f), 2 (2a-2d), 3, 4, 5, 6 & 7

New Hong Kong Tunnel Co Ltd
Lane 14 Hong Kong Bound
Traffic throughput for the period from March 2004 to October 2004

	Motorcycles	Private Cars	Public Light Buses	Light Goods Vehicles	Medium Goods Vehicles	Heavy Goods Vehicles	Single Decker Buses	Double Decker Buses	Taxi	Others	Violations	Total
Mar-04	0	61,114	3,057	19,145	23,045	3,811	8,249	39,054	2,913	14	1,020	161,422
Apr-04	0	52,760	3,240	16,805	20,672	2,566	7,[illegible]88	36,652	2,705	2	1,273	143,957
May-04	0	58,347	3,677	17,832	21,770	3,14[illegible]	8,0[illegible]0	37,646	2,677	16	1,448	154,558
Jun-04	0	56,635	3,232	18,368	22,763	3,098	7,[illegible]80	36,801	2,614	7	1,576	152,774
Jul-04	0	57,250	3,375	19,522	23,906	3,476	8,403	37,949	2,678	4	1,110	157,673
Aug-04	0	57,494	3,362	19,778	23,570	3,081	8,611	38,246	2,693	5	768	157,608
Sep-04	0	60,840	3,763	19,609	23,148	3,024	8,318	36,853	2,976	8	851	159,390
Oct-04	0	59,562	4,039	19,427	22,570	3,240	8,290	37,463	2,691	29	854	158,165
Mar04-Oct04	0	464,002	27,745	150,486	181,444	25,435	64,839	300,664	21,947	85	8,900	1,245,547

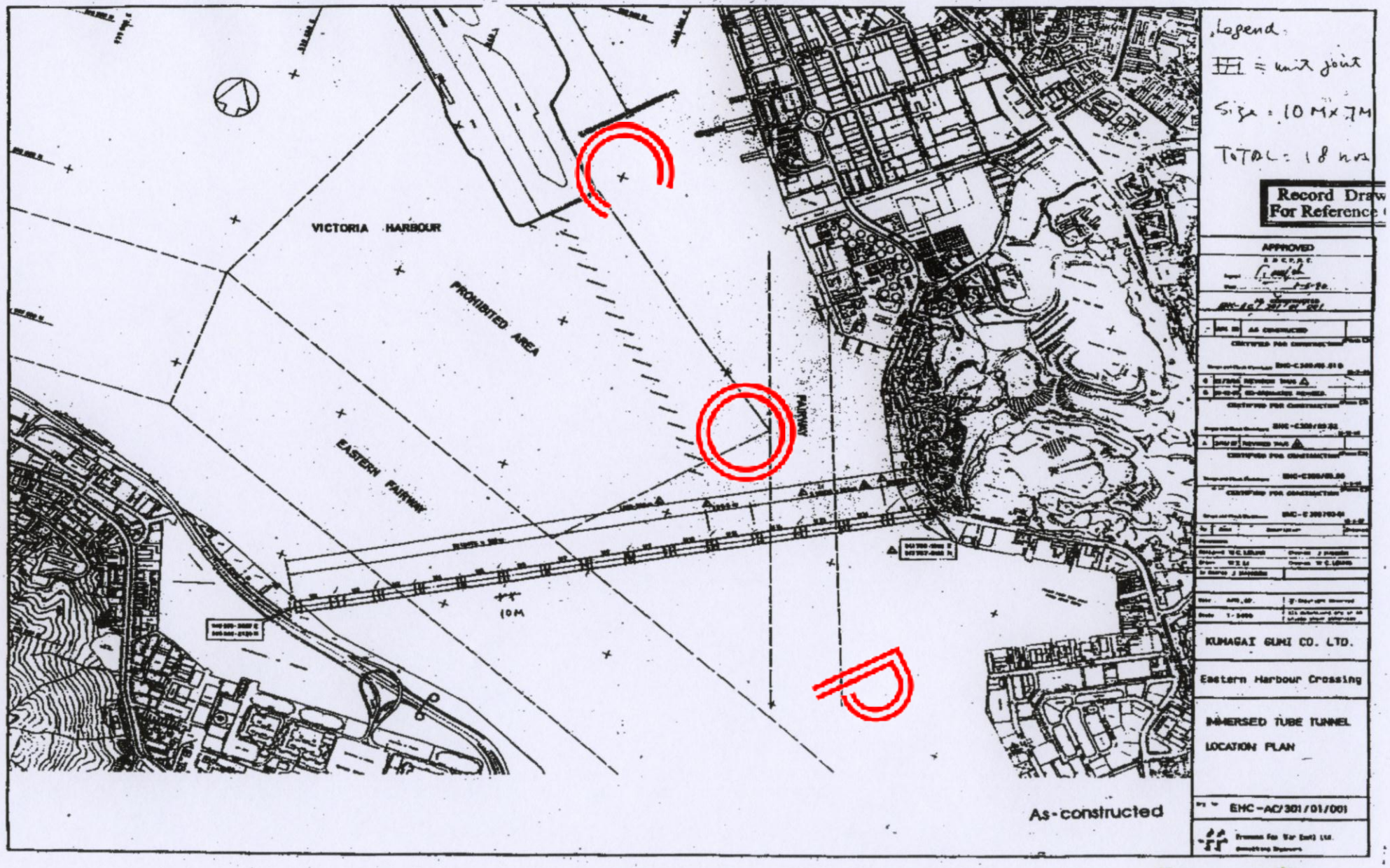


Figure 1 - Location Plan of East Harbour Tunnel

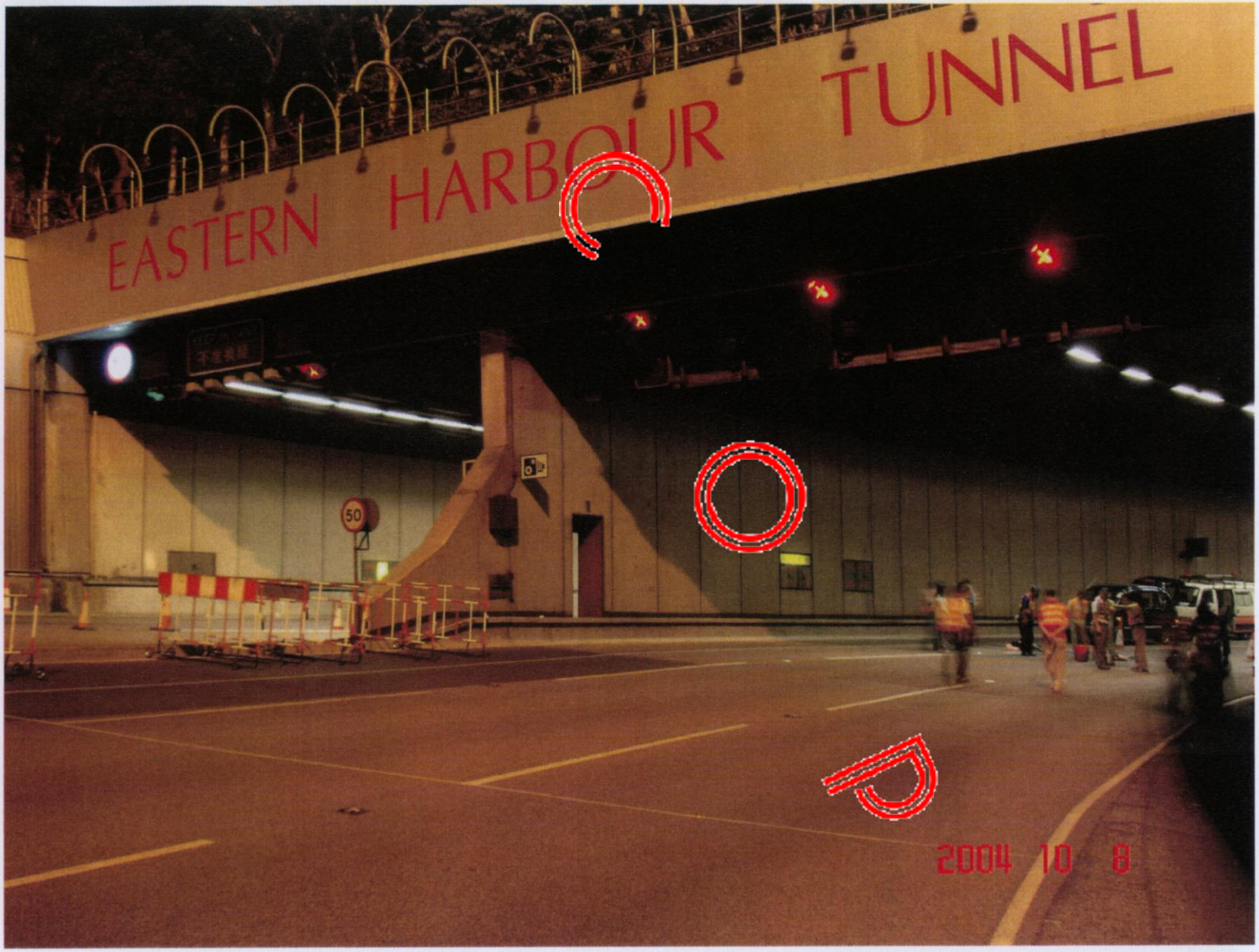


Figure 1a - HK Side Portal of East Harbour Tunnel

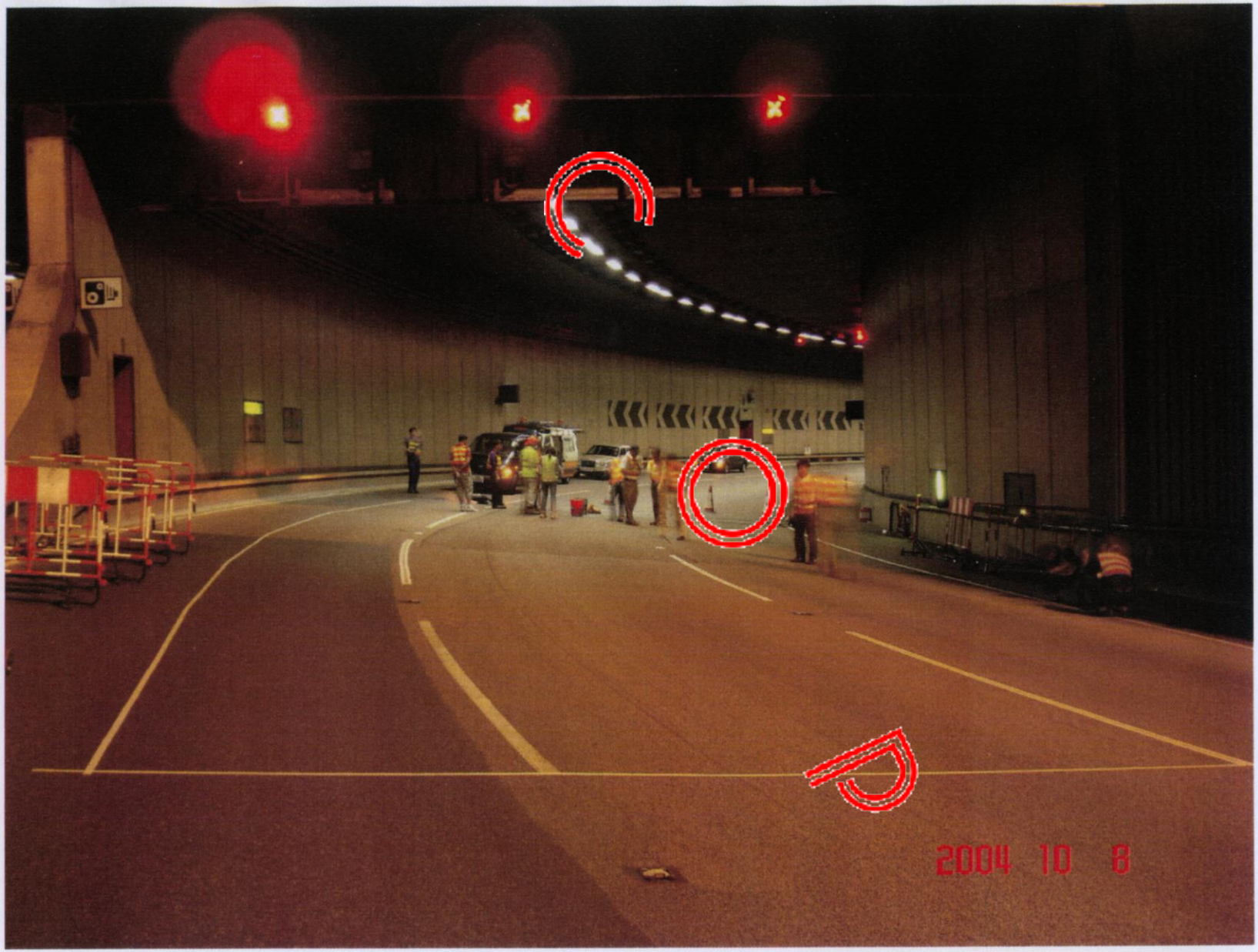


Figure 1b - HK Side Portal of East Harbour Tunnel

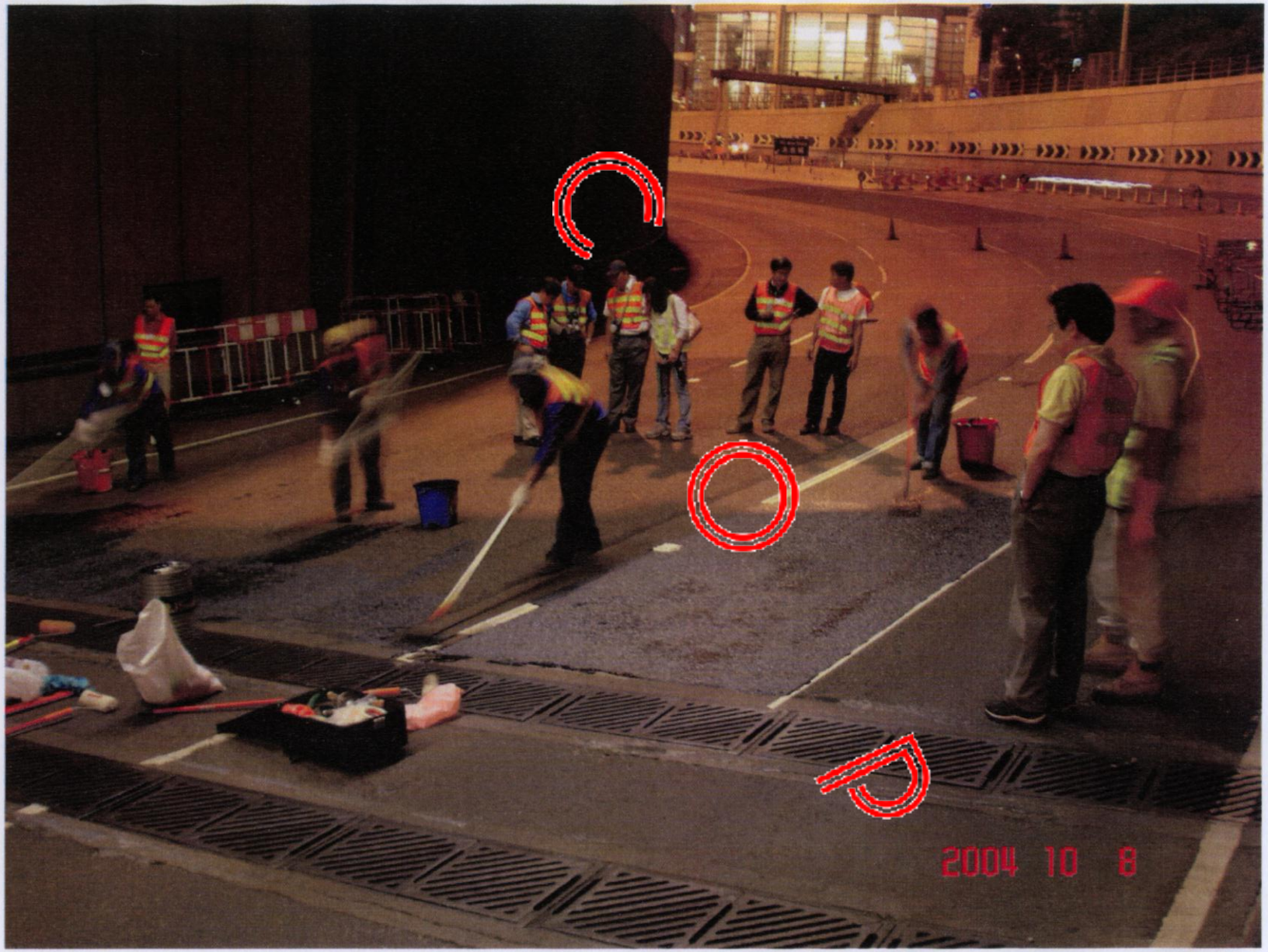


Figure 1c - HK Side Portal of East Harbour Tunnel

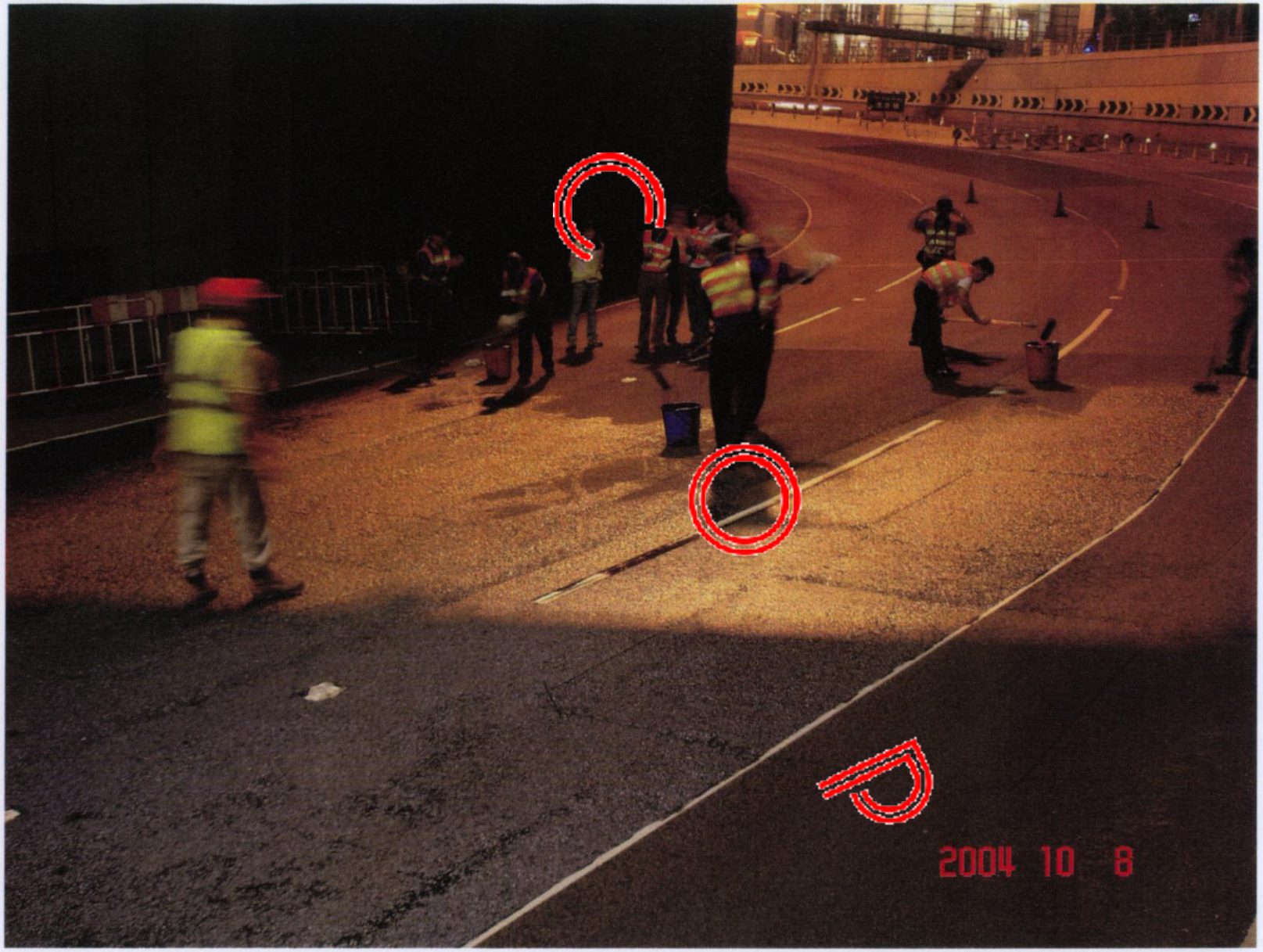


Figure 1d - HK Side Portal of East Harbour Tunnel

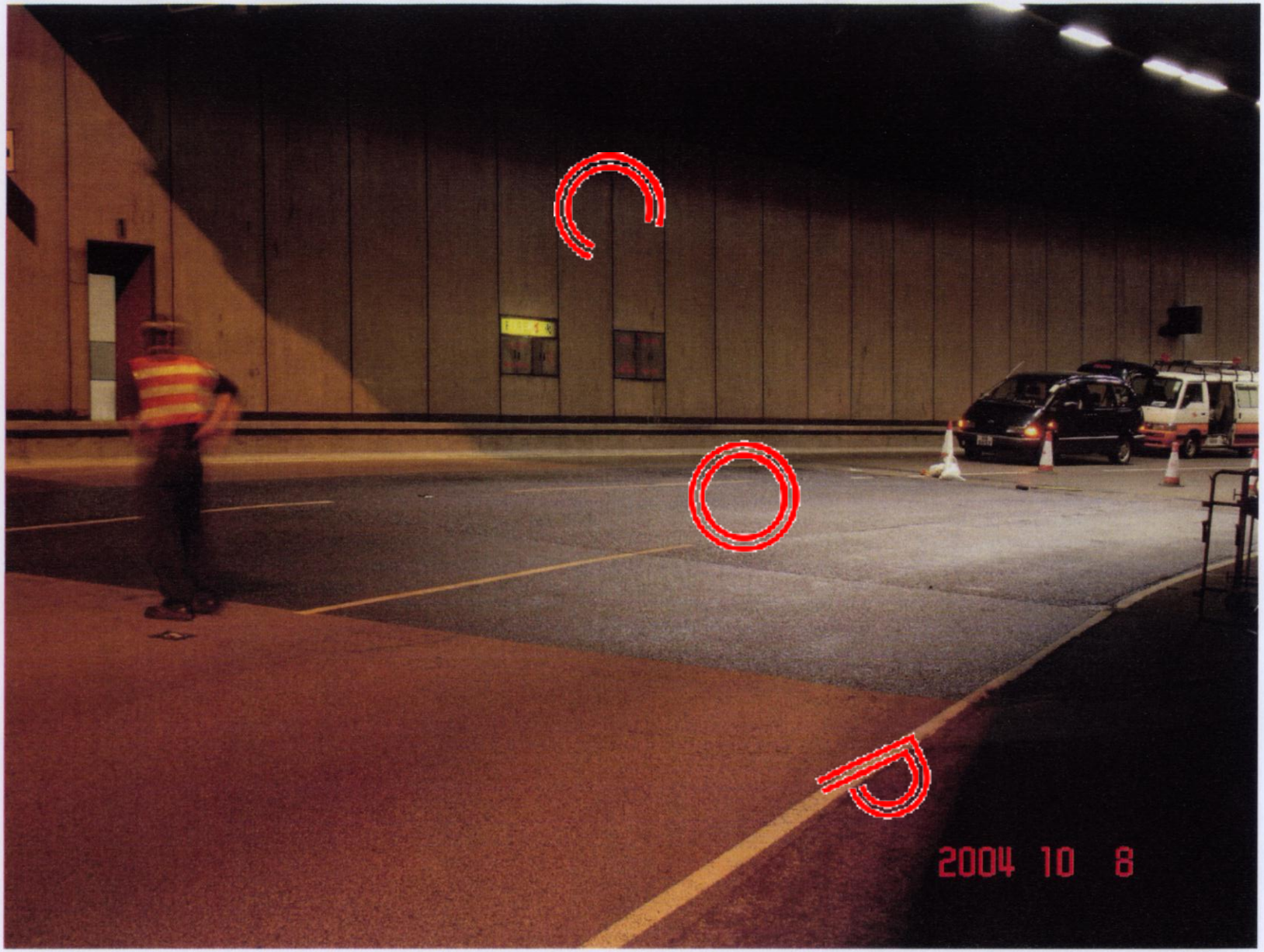


Figure 1e - HK Side Portal of East Harbour Tunnel

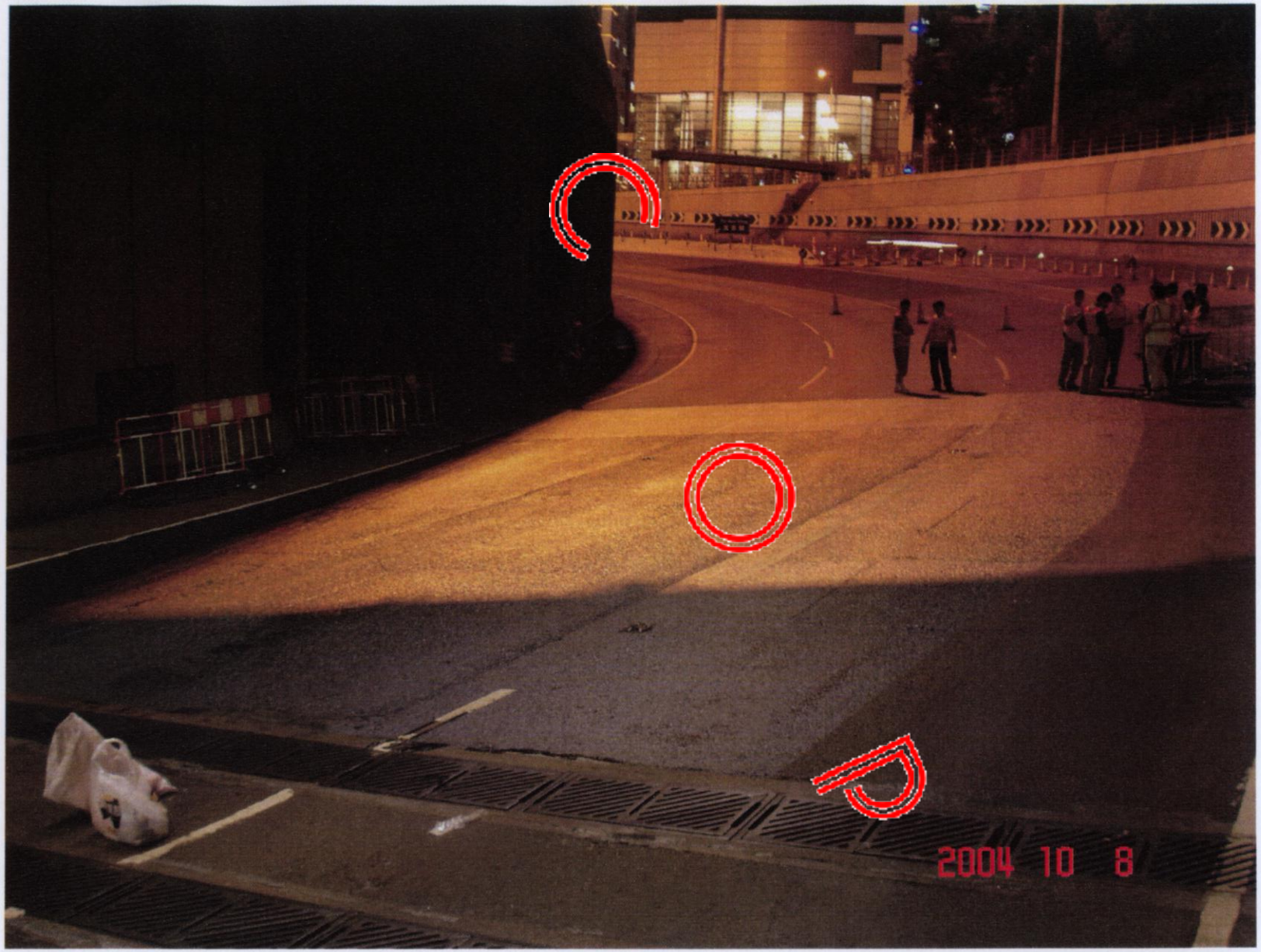


Figure 1f - HK Side Portal of East Harbour Tunnel

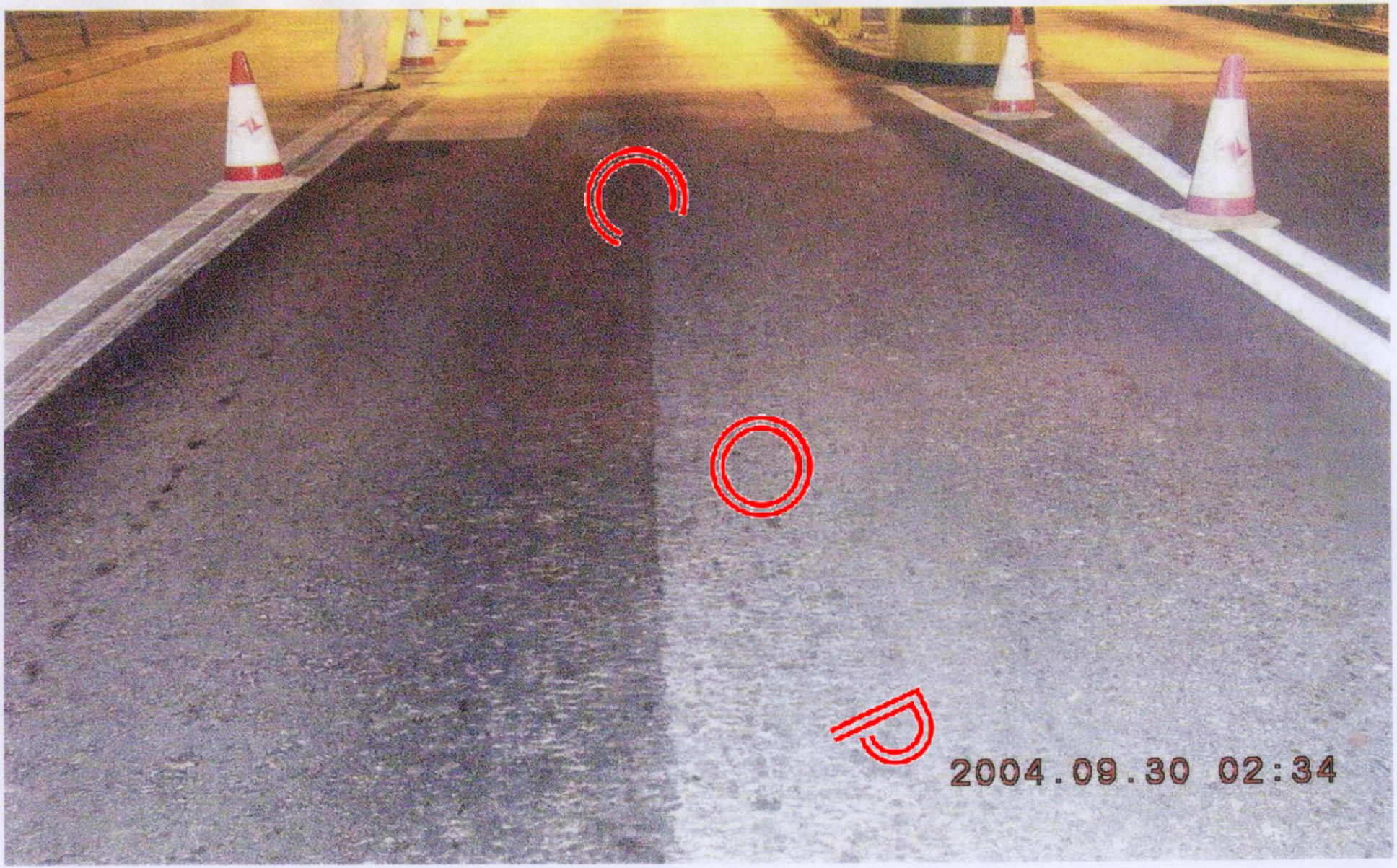


Figure 2 - Test Strip of March 5, 2004
in front of Toll Booth No. 14

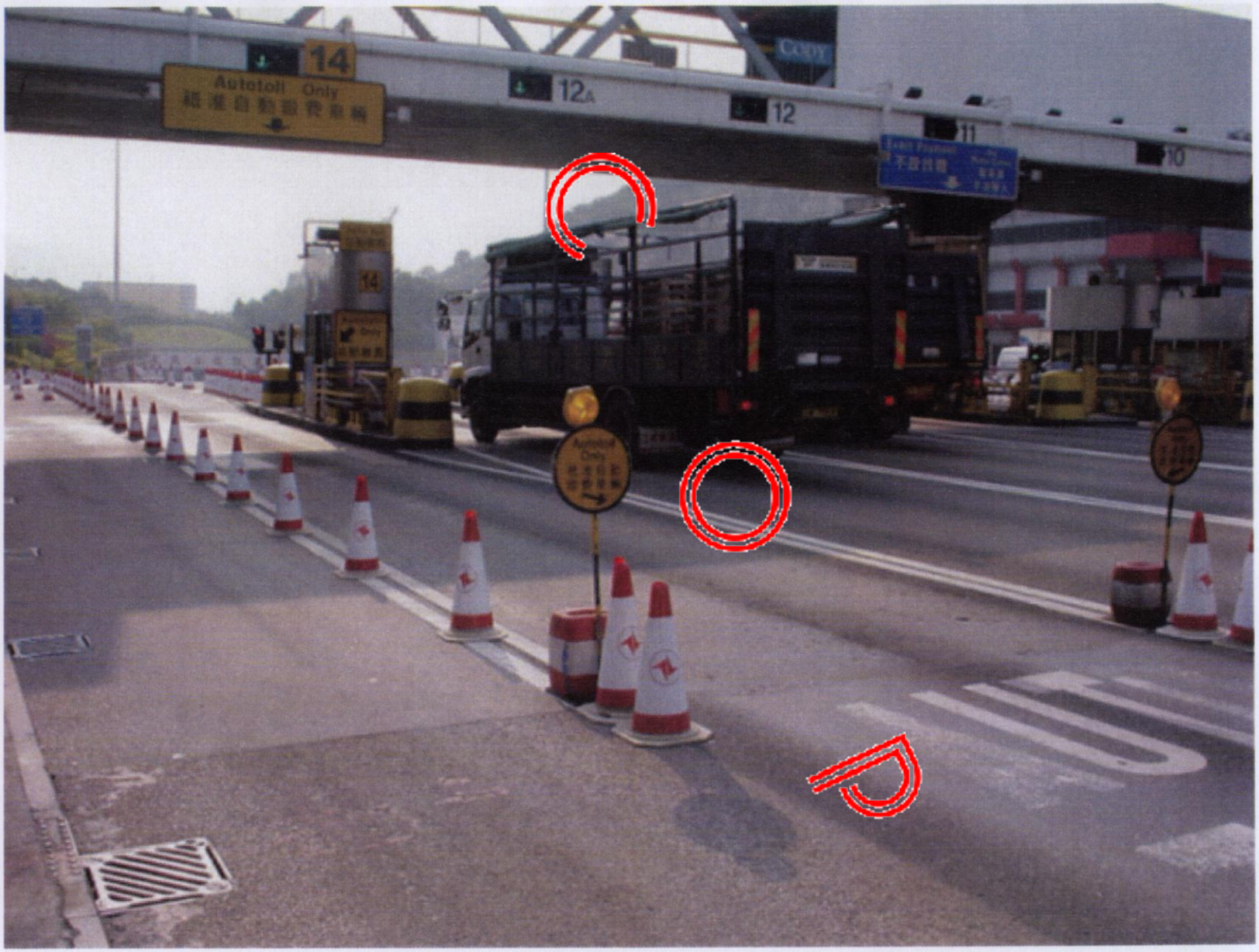


Figure 2a - Test Strip of March 5, 2004
in front of Toll Booth No. 14

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Figure 2b - Test Strip of March 5, 2004
in front of Toll Booth No. 14

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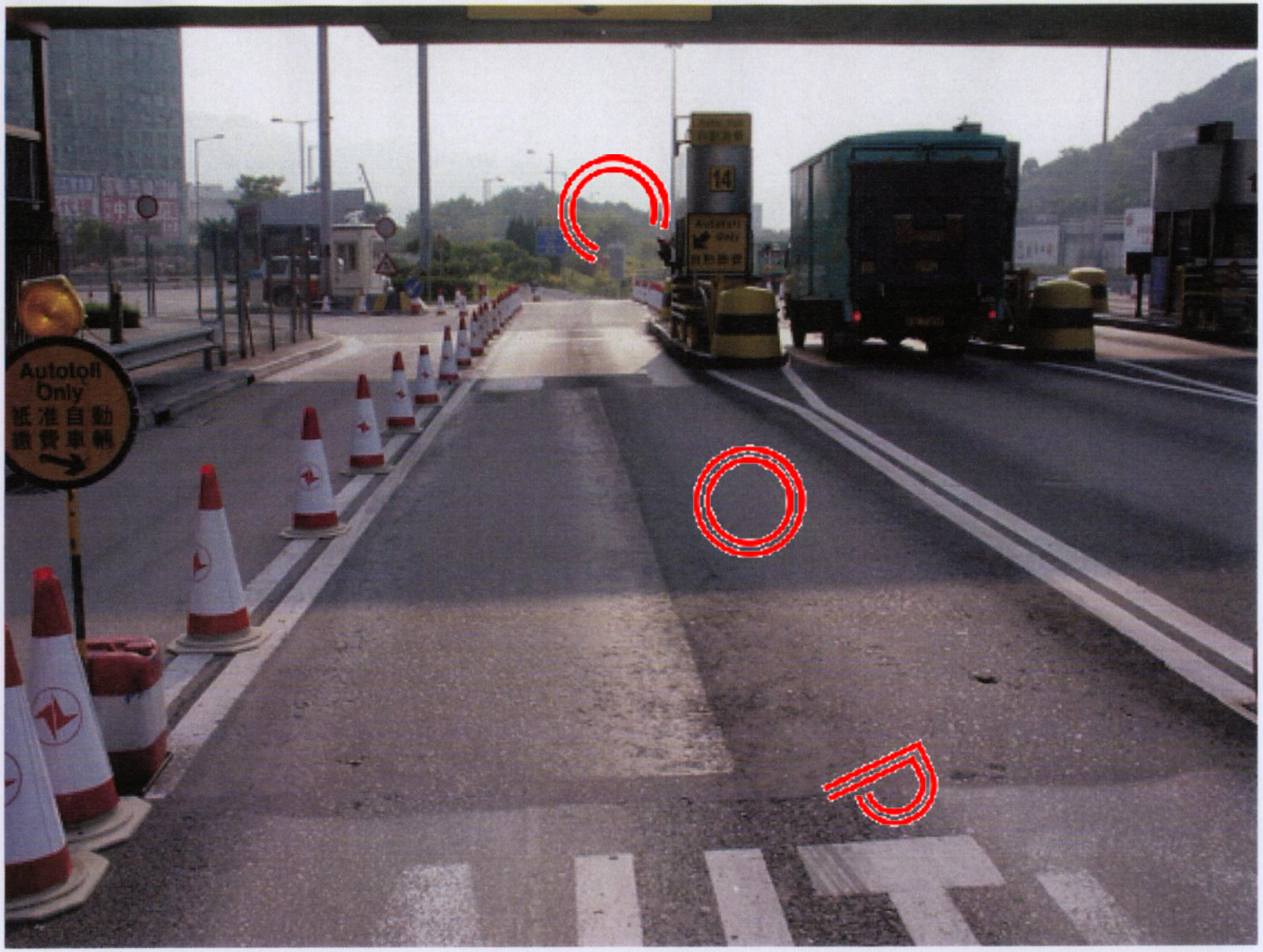

Figure 2c - Test Strip of March 5, 2004
in front of Toll Booth No. 14

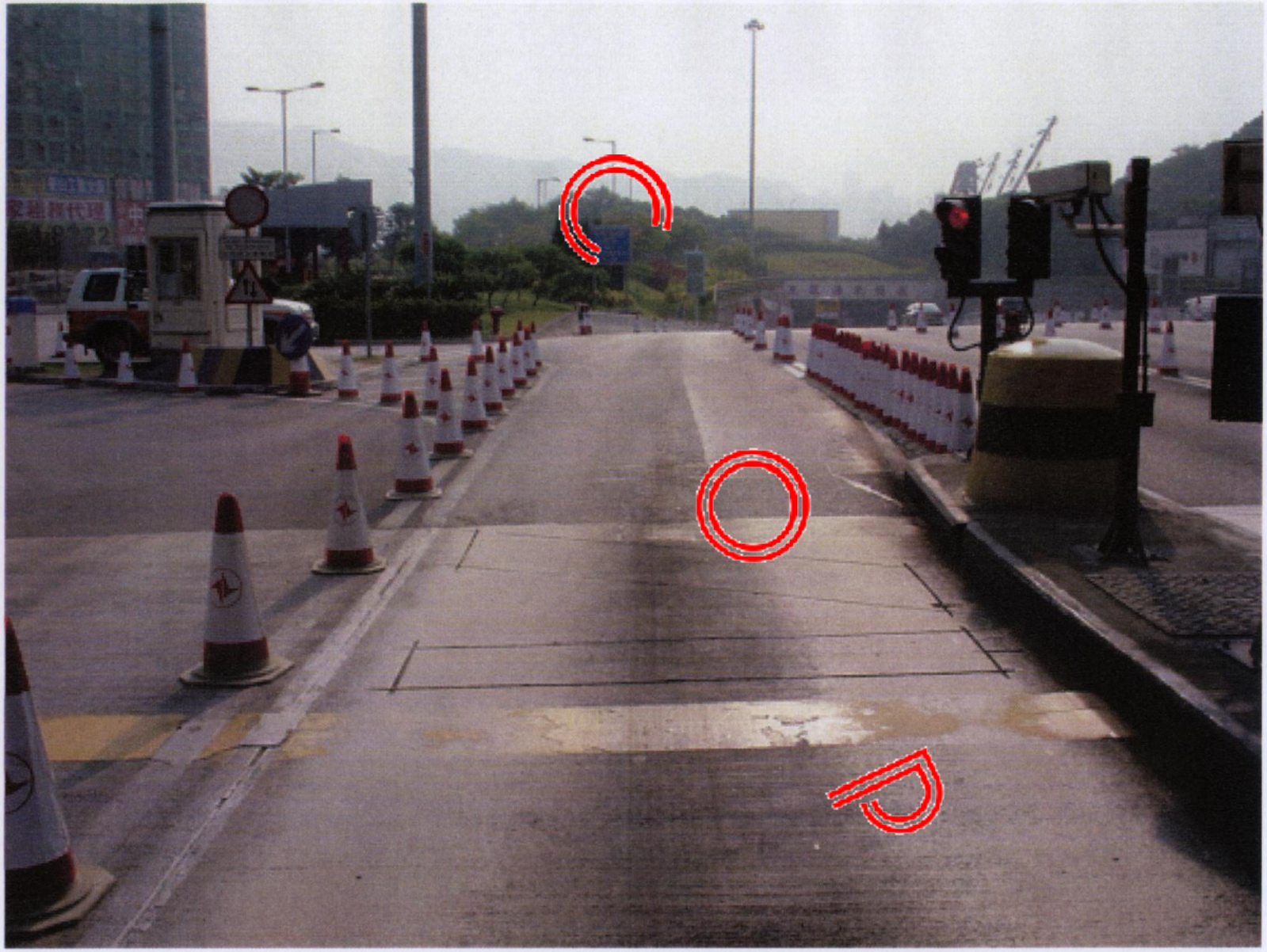

Figure 2d - Test Strip of March 5, 2004
in front of Toll Booth No. 14

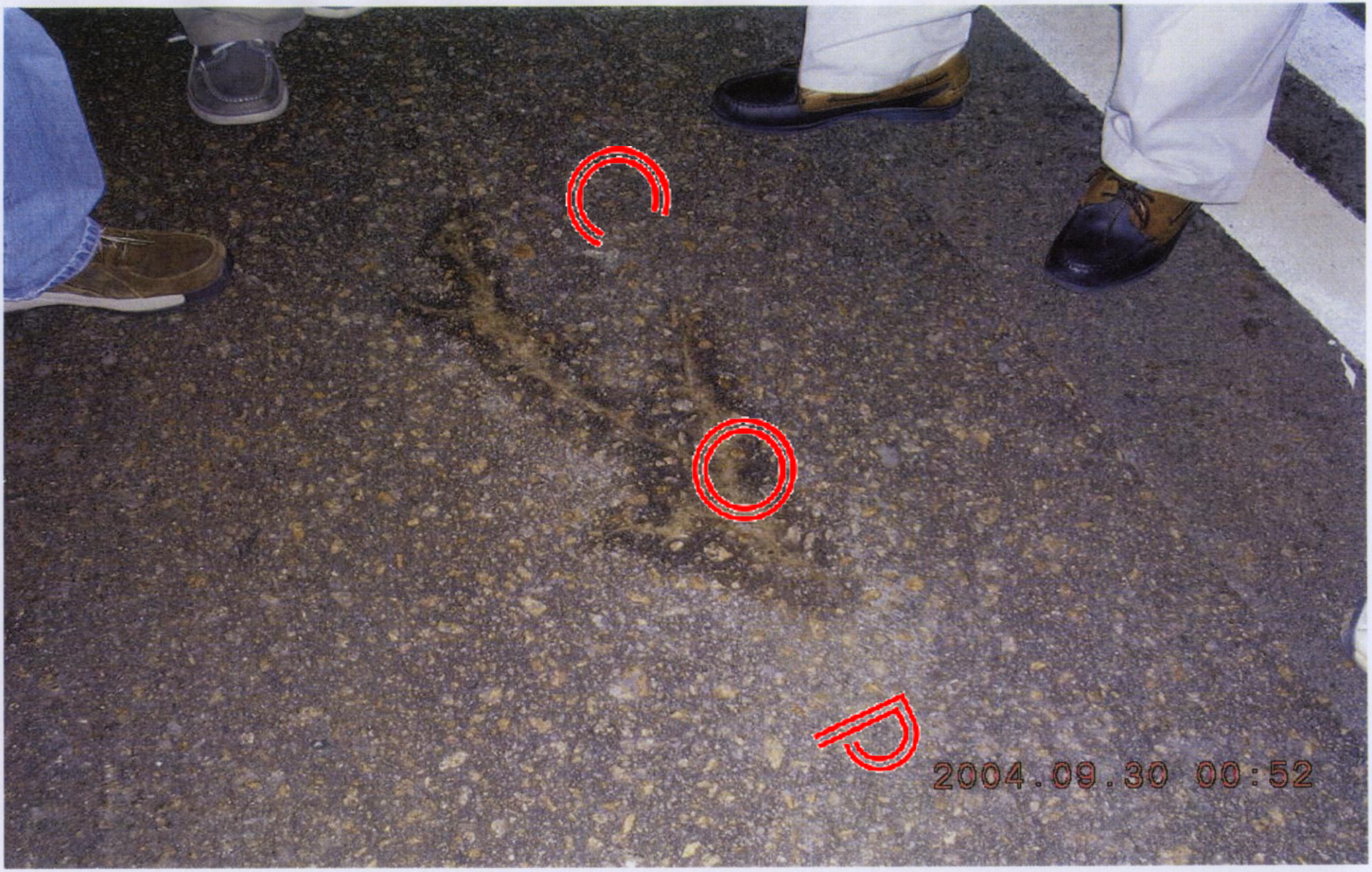

Figure 3 - Water Seepage from Floor

Figure 4 - Damaged Asphalt at Cross Drain

Figure 5 - Exposed Pebbles in Asphalt Pavement

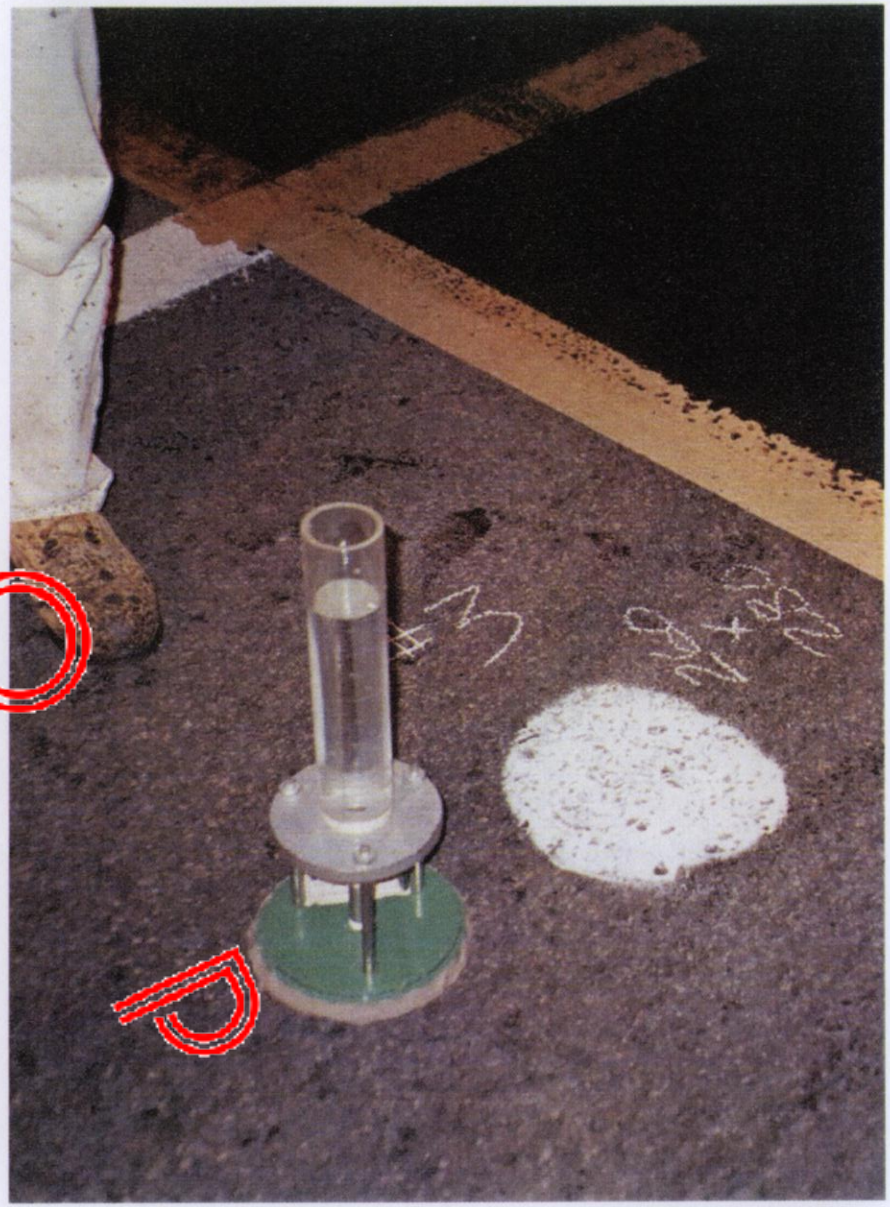

Figure 6 - Humble Equipment Co. Outflow ~~Meter~~
Water Penetration Meter & Sand Patch Test

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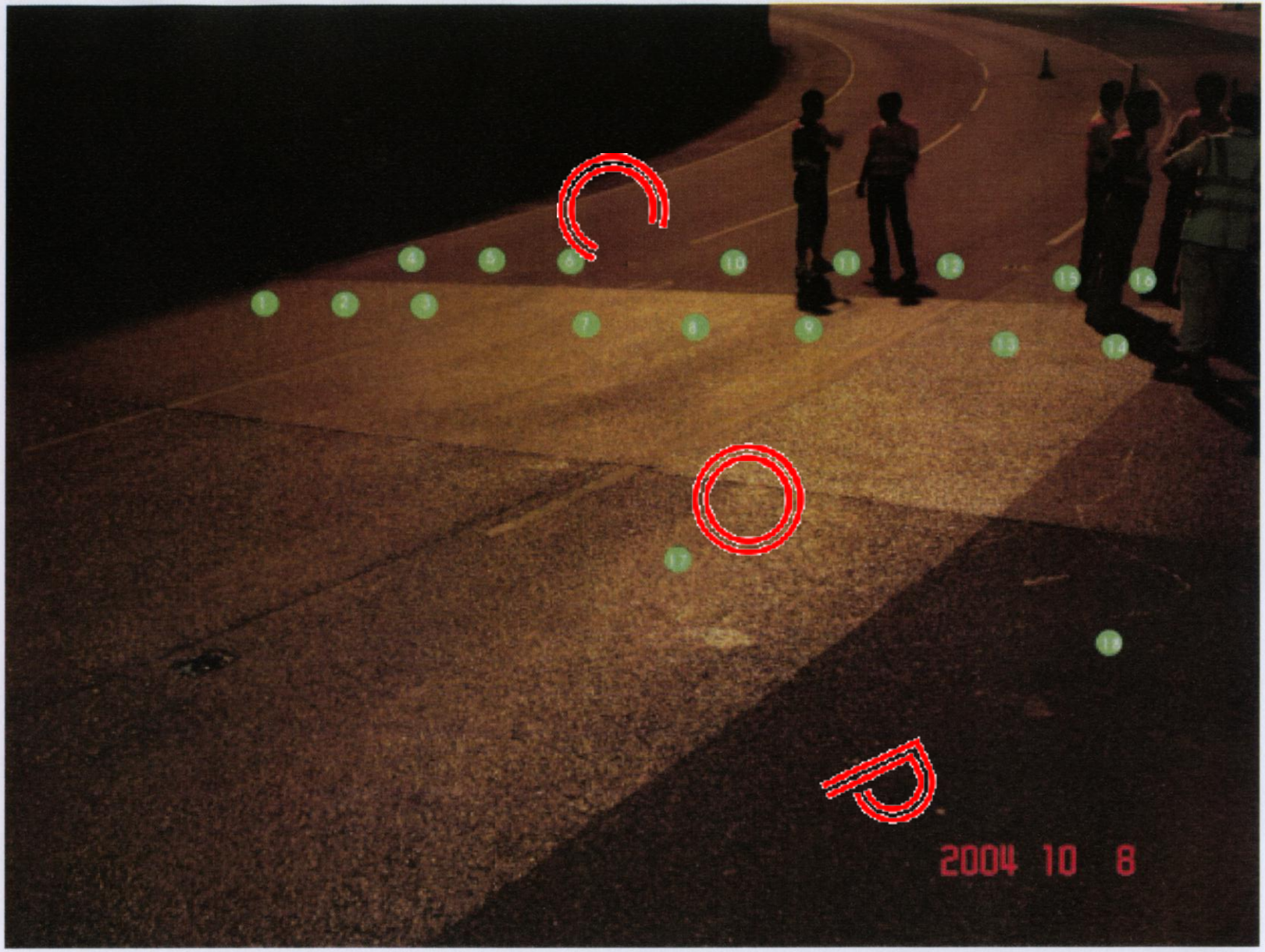

Figure 7 - Locations of RJSeal™ Treated ~~and~~ Untreated Sections