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Mr. Nate Guaff
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Subject: Results of Stack Emission Testing Asphalt Rubber and Conventional Asphalt Concrete

Dear Mr. Guaff:

Please find the enclosed reports of stack emission testing studies conducted at each of two facilities: the Dutra asphalt concrete plant in Richmond and the Mission Valley Rock (MVR) in Sunol, California. The tests were conducted to compare emissions during the production of asphalt rubber concrete (rubberized asphalt) and the production of conventional asphalt concrete (non-rubberized asphalt).

Asphalt rubber concrete is a unique non-proprietary material. It is a combination of aggregate and asphalt rubber binder. The binder consists of approximately 80 percent paving asphalt and asphalt modifier (extender oil) and approximately 20 percent crumb rubber. The crumb rubber consists of approximately 75 percent scrap tire rubber and approximately 25 percent high natural scrap rubber. The binder is field blended and reacted for approximately 45 minutes prior to the introduction into the asphalt concrete plant. Asphalt rubber concrete is usually produced at higher temperatures than conventional asphalt concrete.

The test program tested emissions at each of two asphalt facilities:

- At the Dutra facility, in Richmond, emissions were collected at the outlet of a newly-installed filter/impingement control device that captures emissions from the pug mill mixer (where the asphalt cement is first added to the dried aggregate), the enclosed conveyor downstream of the mixer, the asphalt storage silos, and a shed capture system for the truck load-out area. *It is recognized that emissions measured at this sampling location very likely include exhaust emissions from idling trucks while in the shed enclosure*.
- At the Mission Valley Rock (MVR) facility, in Sunol, emissions were collected at the outlet of the baghouse that controls emissions from the counter-current aggregate drum dryer (where asphalt cement is first added to the dried aggregate), the slat conveyor, the horizontal transfer conveyor, and the asphalt storage silos.

Units of Measure

Emissions are compared on the "pounds per ton of asphalt concrete produced". This parameter reflects the production rates, which varied slightly between the asphalt rubber and the conventional asphalt concrete production conditions:

	Average Production Rate (tons per hour)	
	Conventional Asphalt Concrete	Asphalt Rubber Concrete
Dutra	206	185
MVR	336	307

During all conditions the plant was operated at the maximum capacity that could produce product within specifications. This resulted in production rates that were approximately 10 percent greater during production of conventional asphalt concrete compared with production of asphalt rubber concrete.

Use of the "pounds per ton" parameter is justified for two reasons:

- Plant permit conditions provide annual production limits. For example, MVR's plant is limited, by permit condition, to 600,000 tons per year. This permit condition, in combination with established emission factors, effectively limits the annual emission rate of particulate and toxic compounds.
- The Environmental Protection Agency's (EPA) Compilation of Air Pollutant Emission Factors (AP-42) provides relevant emission factors from asphalt concrete plants in units of "pounds per ton".

Impacts to the Air District

It is recognized that one of the major advantages of asphalt rubber concrete is that it can be designed and placed at approximately one half of the thickness of conventional asphalt concrete and still achieve the desired service life. For example, using conventional pavement design a street resurfacing project may require four inches of conventional asphalt concrete. The same project can be designed with approximately two inches of asphalt rubber concrete. This not only reduces the tonnage of total asphalt concrete placed, but more importantly results in a substantial reduction in total emissions.

By making comparisons on a "pounds per ton" basis, this important factor (reduced thickness) is not considered. However, manufacture of asphalt rubber concrete in the Bay Area results in a substantial reduction in the amount of asphalt concrete produced. If this factor were considered, results could be compared on a "pounds per square yard of pavement" basis, and the asphalt rubber concrete would be substantially more favorable (up to a factor of two).

Control of Variables

During this test program, efforts were made to control as many variables as possible. However, this control of variables must be accomplished within the constraints of customer specifications of the asphalt materials that were being produced. Because the asphalt rubber concrete was manufactured during nighttime hours, and because the binder in the asphalt rubber concrete is more viscous, the required production temperature of the asphalt rubber concrete was greater than the required temperature during the production of conventional asphalt concrete. The table below summarizes product temperatures recorded in each of the two reports (Appendix D). The data suggest that greater emissions may be expected from the asphalt rubber concrete tests simply due to the higher production temperature – and unrelated to the composition of the binder.

	Temperature of Product (° F)	
	Conventional Asphalt Concrete	**Asphalt Rubber Concrete**
Dutra	318	335
MVR	311	318

Particulate Emissions

Particulate emissions during production of asphalt rubber concrete are approximately the same as those from production of conventional asphalt concrete:

	Particulate Emissions (pounds per ton)	
	Conventional Asphalt Concrete	**Asphalt Rubber Concrete**
Dutra	0.0013	0.0015
MVR	0.0025	0.0030

Differences are within the expected error of the method.

It is important to note that particulate emissions during production of asphalt rubber concrete (0.0033 grain/standard cubic foot) are well below the particulate permit condition for this facility (which is limited to 0.01 gr/scf).

Comparison with AP-42

It is important to note that EPA's AP-42 (Chapter 11.1, December 2000) estimates that total particulate emissions from a baghouse filter controlling a drum mix asphalt production operation is 0.033 pound per ton. The MVR plant exhibited much lower particulate emission rates during both production conditions (conventional asphalt concrete and asphalt rubber concrete).

	Particulate Emissions (pounds per ton)	
	Conventional Asphalt Concrete	**Asphalt Rubber Concrete**
MVR	0.0025	0.0030
AP-42	0.0330	0.0330

Measured particulate emissions at the Dutra facility cannot be compared with AP-42, because AP-42 only provides particulate data from the main plant stack (which exhausts emissions from the aggregate dryer).

Toxic Air Contaminants

In order to compare the toxic emissions during the production of conventional asphalt concrete with those from asphalt rubber concrete, the measured emissions of each contaminant were interpreted with respect to the potency of each of the various contaminants. The annual emission thresholds (in units of pounds per year) that are listed in Bay Area Air Quality Management District (BAAQMD) Regulation 2-1-316 were used as the index of potency, compared with regulatory limits for toxic emissions:

- The Toxic Potency Index for each contaminant was calculated by dividing the measured Emission Factor (pounds per ton) by the Annual Emission Threshold (pounds per year).
- The sum of the various Toxic Potency Index values is the Toxic Potency Index of those emissions.

	Reg 2-1-316 Threshold (lbs./year)	**Toxic Potency Index**			
		Dutra		**MVR**	
		Conventional Asphalt Concrete	Asphalt Rubber Concrete	**Conventional Asphalt Concrete**	**Asphalt Rubber Concrete**
Benzene	**6.7**	1.90E-07	5.12E-06	6.32E-06	5.40E-06
Toluene	**39,000**	5.77E-11	1.99E-09	5.20E-10	4.64E-10
Xylene	**58,000**	0	1.42E-08	3.40E-10	8.93E-10
1,3-Butadiene	**1.1**	0	0	5.00E-06	6.20E-06
Naphthalene	**270**	4.89E-08	5.35E-08	1.16E-08	2.17E-08
Benz(a)anthracene	**0.044**	2.73E-08	0	0	0
otal Toxic Potency Index		**2.66E-07**	**5.19E-06**	**1.13E-05**	**1.16E-05**

The data above indicates that at the MVR facility, the total toxic Potency Index is approximately the same during production of conventional asphalt concrete and asphalt rubber concrete.

At the Dutra facility, the Total Toxic Potency Index was twenty-fold greater during the production of asphalt rubber concrete compared to the Index calculated from conventional asphalt concrete. The greater Index was due, primarily, to the greater measured emissions of benzene during the production of asphalt rubber concrete. The most likely source of the benzene is from tailpipe exhaust, which was captured (along with asphalt production emissions) in the truck load-out shed. The source of the additional benzene emission is not likely from the crumb rubber in the asphalt rubber concrete. The only other added component in the asphalt rubber concrete is an extender oil. Benzene is not a component that is listed on the Material Safety Data Sheet (MSDS) for the extender oils. The industry has tested the extender oil that has been used in the asphalt rubber binder on a number of projects and the analysis indicates that it does not contribute to the emissions of benzene.

Comparison of Toxic Emissions With AP-42

The measured emission factors of toxic compounds and other chemical species during the production of both conventional asphalt concrete and asphalt rubber concrete at Dutra were generally lower than the AP-42 emission factors for a batch-mix asphalt plant.

	Emission Factor (pounds per ton)		
	Conventional Asphalt Concrete	**Asphalt Rubber Concrete**	**AP-42 (Batch Mix)**
Benzene	1.27E-06	3.43E-05	2.80E-04
Toluene	2.25E-06	7.75E-05	1.00E-03
Ethyl Benzene	0	7.37E-06	2.20E-03
Xylene	0	8.26E-04	2.70E-03
1,3-Butadiene	0	0	Not Avail.
Naphthalene	1.32E-05	1.45E-05	3.60E-05
2-Methylnaphthalene	1.12E-05	2.15E-05	7.10E-05
Acenaphthylene	3.43E-07	3.99E-07	5.80E-07
Acenaphthene	1.05E-06	1.63E-06	9.00E-07
Fluroene	6.61E-07	1.37E-06	1.60E-06
Phenanthrene	1.28E-06	1.83E-06	2.60E-06
Anthacene	4.09E-07	5.04E-07	2.10E-07
Fluoranthene	6.15E-08	4.00E-08	1.60E-07
Pyrene	2.78E-07	1.64E-07	Not Avail.
Benz(a)anthracene	1.20E-09	0	4.60E-09
Chrysene	7.55E-09	2.55E-09	3.80E-09
Benzo(b)fluoranthene	0	0	9.40E-09
Benzo(k)fluoranthene	0	0	1.30E-08
Benzo(e)pyrene	5.56E-09	2.82E-09	Not Avail.
Benzo(a)pyrene	0	0	3.10E-10
Perylene	1.51E-09	0	Not Avail.
Indeno(1,2,3-c,d)pyrene	0	0	3.00E-10
Dibenz(a,h)anthracene	0	0	9.50E-11
Benzo(g,h,l)perylene	0	0	Not Avail.

Similarly, the measured emission factors of toxic compounds and other chemical species during the production of both conventional asphalt concrete and asphalt rubber concrete at MVR were consistently lower than the AP-42 emission factors for a drum-mix asphalt concrete plant.

	Emission Factor (pounds per ton)		
	Conventional Asphalt Concrete	**Asphalt Rubber Concrete**	**AP-42 (Drum Mix)**
Benzene	4.23E-05	3.62E-05	3.90E-04
Toluene	2.03E-05	1.81E-05	1.50E-04
Ethyl Benzene	0	3.20E-06	2.40E-04
Xylene	1.97E-05	5.18E-05	2.00E-04
1,3-Butadiene	5.50E-06	6.82E-06	Not Avail.
Naphthalene	3.12E-06	5.87E-06	9.00E-05
2-Methylnaphthalene	7.78E-07	1.60E-06	7.40E-05
Acenaphthylene	1.71E-07	1.01E-07	8.60E-06
Acenaphthene	1.66E-08	1.86E-09	1.40E-06
Fluroene	5.27E-08	3.68E-08	3.80E-06
Phenanthrene	1.09E-07	8.02E-08	7.60E-06
Anthacene	1.19E-07	4.79E-09	2.20E-07
Fluoranthene	8.28E-09	4.04E-09	6.10E-07
Pyrene	1.16E-09	3.52E-09	Not Avail.
Benz(a)anthracene	0	0	2.10E-07
Chrysene	0	0	1.80E-07
Benzo(b)fluoranthene	0	0	1.00E-07
Benzo(k)fluoranthene	0	0	4.10E-08
Benzo(e)pyrene	0	0	1.10E-07
Benzo(a)pyrene	0	0	9.80E-09
Perylene	0	0	8.80E-09
Indeno(1,2,3-c,d)pyrene	0	0	7.00E-09
Dibenz(a,h)anthracene	0	0	Not Avail.
Benzo(g,h,l)perylene	0	0	4.00E-08

Summary and Conclusions

In summary, measured emissions of particulate and specified toxic compounds during the production of asphalt rubber concrete were not significantly greater, if greater at all, than the emissions during the production of conventional asphalt concrete. Also, measured emission rates of particulate and toxic compounds were consistently lower than the emission factors indicated in EPA's AP-42 emission factors for asphalt concrete plants.

In conclusion, these data indicate that emissions from the production of asphalt rubber concrete are not significantly different than those from the production on conventional asphalt concrete. Asphalt rubber is one of many types of “asphalt binders”, and emissions from production of asphalt rubber concrete are not dissimilar to the emissions from the production of conventional asphalt concrete.

Since asphalt rubber concrete is routinely placed in reduced thickness (when compared to conventional asphalt concrete) the total emissions generated on a project basis should be substantially less than the total emissions for a conventional asphalt concrete project. Therefore, existing production plants in the Bay Area that are permitted to produce asphalt concrete, should thereby also be permitted to produce asphalt rubber concrete.

Acknowledgements

On behalf of the various parties that have contributed to this testing program, I wish to express my appreciation in working with the professional staff of the Bay Area Air Quality Management District. I would like to especially acknowledge Mark Belshe, Chairman of the RPA Environmental Committee, Doug Carlson, Don Stout, Mike Justice, Fred Cooper, Greg Stone, and Tim Underwood for their time and effort that was put into this study. Without their efforts this study would not have been successful. I also would like to thank you and the California Integrated Waste Management Board, whose help in funding this program were indispensable.

If you should require further information, please contact me at (916) 874-7225.

Sincerely,

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