BOARD OF COUNTY COMMISSIONERS OF DOUGLAS COUNTY, KANSAS

WEDNESDAY, MARCH 26, 2014
4:00 p.m.

CONSENT AGENDA
(1) (a) Consider approval of Commission Orders;
    (b) Consider awarding construction contract for deck rehabilitation work on Bridge Nos. 11.00N-16.40E and 11.72N-17.50E, Project Nos. 2013-15 & 2013-16 (Keith Browning)

REGULAR AGENDA
(2) Consider approval of ZTBU-2014-0002, a Temporary Business Permit for a Concrete Batch Plant, to be located south and east of where the Mary's Lake caretaker's house was located at1535 N 1300 Road, Lawrence, KS as deferred from the 03-19-14 meeting (Linda Finger)

(3) (a) Consider approval of Accounts Payable (if necessary)
    (b) Appointments
    Bert Nash Community Health Center Board of Directors (2) expire 04/2014
    Heritage Conservation Council (3) positions expire 05/31/2014
    Jayhawk Area Agency on Aging Board of Directors – (2) vacancies
    Jayhawk Area Agency on Aging Tri-County Advisory Council – (2) vacancies
    Lawrence-Douglas County Housing Authority (1) position expires 06/2014
    (c) Public Comment
    (d) Miscellaneous

(4) Adjourn

WEDNESDAY, APRIL 2, 2014
4:00 p.m.
Proclamation for "Child Abuse Prevention Month"
Proclamation for **"**National Public Health Week, April 7 – 13, 2014" (Dan Partridge)

-Approval of Health Insurance Stop-Loss Coverage (Sarah Plinsky)
-TA-13-00451: Consider a Text Amendment to Section 12-319-7 of the Zoning Regulations for the Unincorporated Territory of Douglas County, Kansas to establish criteria and review process for Agritourism uses which may have significant off-site impacts. *(Amendment was initiated by the Board of County Commissioners at their October 16, 2013 meeting.)* Mary Miller will present the item.

MONDAY, APRIL 7, 2014
9:00 a.m. – Lecompton Election Canvass

WEDNESDAY, APRIL 9, 2014

WEDNESDAY, APRIL 16, 2014
-Proclamation for National Public Safety Telecommunicator's Week April 13-19, 2014 (Scott Ruff)

WEDNESDAY, APRIL 23, 2014

WEDNESDAY, APRIL 30, 2014
4:00 p.m.
-Presentation of Report from Lawrence-Douglas County Advocacy Council on Aging (Judy Bellome)

***Note**: The Douglas County Commission meets regularly on Wednesdays at 4:00 P.M. for administrative items and 6:35 P.M. for public items at the Douglas County Courthouse. Specific regular meeting dates that are not listed above have not been cancelled unless specifically noted on this schedule.*

DOUGLAS COUNTY PUBLIC WORKS
1242 Massachusetts Street
Lawrence, KS 66044-3350
(785) 832-5293 Fax (785) 841-0943
dgcopubw@douglas-county.com
www.douglas-county.com

Keith A. Browning, P.E.
Director of Public Works/County Engineer

MEMORANDUM

To : Board of County Commissioners

From : Keith A. Browning, P.E., Director of Public Works/County Engineer

Date : March 21, 2014

Re : Consider awarding construction contract for silica fume overlays
Bridge Nos. 11.00N-16.40E and 11.72N-17.50E
Project Nos. 2013-15 & 2013-16

Bids were opened March 20 for deck rehabilitation work on the referenced two bridges (see attached bid tab). The deck rehabilitation work includes patching and overlaying both bridge decks with silica fume concrete. Three contractors submitted bids as follows:

Bidder	Total Bid
Wildcat Construction	$256,475.00
Mill Valley Construction	$274,152.50
PCI Roads	$287,144.23
Engineer's Estimate	*$262,577.00*

The approved CIP includes $394,000 for these two projects combined.

We plan for construction to commence in mid- to late-April. The contract stipulates Bridge No. 11.00N-16.40E will be opened by July 1, and Bridge No. 11.72N-17.50E will be opened by July 18. The bridges will be closed to all traffic during the work.

The bid assumes a total 422 square yards of concrete bridge deck will require patching. However, if additional patching is required the final construction cost will exceed the bid amount accordingly. Due to this uncertainty, we request authorization for the Public Works Director to approve change orders up to 10% of the total contract cost.

Action Required: Consent Agenda approval of construction contract with the low bidder, Wildcat Construction, in the total bid amount of $256,475.00 for Project Nos. 2013-15 and 2013-16, bridge deck rehabilitation for Bridges No. 11.00N-16.40E and 11.72N-17.50E, and authorize Public Works Director to approve change orders totaling up to 10% of the contract cost.

DOUGLAS COUNTY PUBLIC WORKS
PROJECT 2013-15 & 2013-16/BID NO. 14-F-0006
DESCRIPTION: Br. #11.00N-16.40E AND Br. #11.72N-17.50E
BID TABULATION
March 20, 2014

Br. #11.00N-16.40E				**ENGINEER'S ESTIMATE**		**WILDCAT CONCRETE**		**MILL VALLEY CONSTR.**		**PCI ROADS**	
ITEM #	DESCRIPTION	APPROX QUANTITY	UNIT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT
1	Milling	556	S.Y.	$4.00	$2,224.00	$6.00	$3,336.00	$6.00	$3,336.00	$11.47	$6,377.32
2	HMA – Commercial Grade (Class A)	66	Tons	$85.00	$5,610.00	$120.00	$7,920.00	$105.00	$6,930.00	$193.00	$12,738.00
3	HMA – Commercial Grade (Class A) (Patch)	20	Tons	$200.00	$4,000.00	$175.00	$3,500.00	$205.00	$4,100.00	$1.00	$20.00
4	Machine Preparation (0.75")	678	S.Y.	$15.00	$10,170.00	$25.00	$16,950.00	$18.00	$12,204.00	$25.00	$16,950.00
5	Area Prepared for Patching	270	S.Y.	$225.00	$60,750.00	$225.00	$60,750.00	$250.00	$67,500.00	$70.00	$18,900.00
6	Area Prepared for Patching (Full Depth)	5	S.Y.	$300.00	$1,500.00	$400.00	$2,000.00	$315.00	$1,575.00	$87.50	$437.50
7	Silica Fume Overlay (1.5")	678	S.Y.	$65.00	$44,070.00	$40.00	$27,120.00	$60.00	$40,680.00	$67.00	$45,426.00
8	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00
9	Reinforcing Steel (Gr.60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
10	Mobilization	1	L.S.	$10,000.00	$10,000.00	$15,000.00	$15,000.00	$11,500.00	$11,500.00	$31,560.00	$31,560.00
11	Traffic Control	1	L.S.	$3,500.00	$3,500.00	$5,000.00	$5,000.00	$3,450.00	$3,450.00	$14,254.00	$14,254.00
			TOTAL BID		$142,002.00		$141,754.00		$151,453.00		$146,840.82

Br. #11.72N-17.50E				**ENGINEER'S ESTIMATE**		**WILDCAT CONCRETE**		**MILL VALLEY CONSTR.**		**PCI ROADS**	
ITEM #	DESCRIPTION	APPROX QUANTITY	UNIT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT
1	Milling	553	S.Y.	$4.00	$2,212.00	$6.00	$3,318.00	$6.00	$3,318.00	$11.47	$6,342.91
2	HMA – Commercial Grade (Class A)	63	Tons	$85.00	$5,355.00	$120.00	$7,560.00	$105.00	$6,615.00	$193.00	$12,159.00
3	HMA – Commercial Grade (Class A) (Patch)	20	Tons	$200.00	$4,000.00	$175.00	$3,500.00	$205.00	$4,100.00	$1.00	$20.00
4	Machine Preparation (0.75")	711	S.Y.	$15.00	$10,665.00	$25.00	$17,775.00	$18.50	$13,153.50	$25.00	$17,775.00
5	Area Prepared for Patching	142	S.Y.	$225.00	$31,950.00	$225.00	$31,950.00	$250.00	$35,500.00	$70.00	$9,940.00
6	Area Prepared for Patching (Full Depth)	5	S.Y.	$300.00	$1,500.00	$400.00	$2,000.00	$315.00	$1,575.00	$87.50	$437.50
7	Silica Fume Overlay (1.5")	711	S.Y.	$65.00	$46,215.00	$40.00	$28,440.00	$60.00	$42,660.00	$67.00	$47,637.00
8	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00
9	Reinforcing Steel (Gr.60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
10	Mobilization	1	L.S.	$15,000.00	$15,000.00	$15,000.00	$15,000.00	$11,500.00	$11,500.00	$31,560.00	$31,560.00
11	Traffic Control	1	L.S.	$3,500.00	$3,500.00	$5,000.00	$5,000.00	$4,100.00	$4,100.00	$14,254.00	$14,254.00
			TOTAL BID		$120,575.00		$114,721.00		$122,699.50		$140,303.41

COMBINED BID AMOUNT	$262,577.00	$256,475.00	$274,152.50	$287,144.23

Keith A. Browning, PE, Director of Public Works Date: Jaime Shew, Douglas County Clerk

DOUGLAS COUNTY PUBLIC WORKS
PROJECT 2013-15 & 2013-16/BID NO. 14-F-0006
DESCRIPTION: Br. #11.00N-16.40E AND Br. #11.72N-17.50E
BID TABULATION
March 20, 2014

Br. #11.00N-16.40E

ITEM #	DESCRIPTION	APPROX QUANTITY	UNIT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT
1	Milling	556	S.Y.								
2	HMA – Commercial Grade (Class A)	66	Tons								
3	HMA – Commercial Grade (Class A) (Patch)	20	Tons								
4	Machine Preparation (0.75")	678	S.Y.								
5	Area Prepared for Patching	270	S.Y.								
6	Area Prepared for Patching (Full Depth)	5	S.Y.								
7	Silica Fume Overlay (1.5")	678	S.Y.								
8	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00
9	Reinforcing Steel (Gr.60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
10	Mobilization	1	L.S.								
11	Traffic Control	1	L.S.								
			TOTAL BID								

Br. #11.72N-17.50E

ITEM #	DESCRIPTION	APPROX QUANTITY	UNIT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT	UNIT COST	AMOUNT
1	Milling	533	S.Y.								
2	HMA – Commercial Grade (Class A)	63	Tons								
3	HMA – Commercial Grade (Class A) (Patch)	20	Tons								
4	Machine Preparation (0.75")	711	S.Y.								
5	Area Prepared for Patching	142	S.Y.								
6	Area Prepared for Patching (Full Depth)	5	S.Y.								
7	Silica Fume Overlay (1.5")	711	S.Y.								
8	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00	$175.00
9	Reinforcing Steel (Gr.60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00
10	Mobilization	1	L.S.								
11	Traffic Control	1	L.S.								
			TOTAL BID								

COMBINED BID AMOUNT

Keith A. Browning, PE, Director of Public Works Date: Jaime Shew, Douglas County Clerk

8

DOUGLAS COUNTY, KANSAS

OFFICE OF THE COUNTY ENGINEER

SPECIFICATIONS AND CONTRACT DOCUMENTS

FOR

DOUGLAS COUNTY PROJECT NO. 2013-15 (Br. #11.00N-16.40E) OVER COAL CREEK
AND
DOUGLAS COUNTY PROJECT NO. 2013-16 (Br. #11.72N-17.50E) OVER THE WAKARUSA RIVER

BID #14-F-0006

Douglas County Commissioners

Mike Gaughan, Chairman

Jim Flory, Member

Nancy Thellman, Member

Approved By:

Keith A. Browning, P.E.
Director of Public Works
and County Engineer

Date: 2/24/14

RECEIVED
MAR 13 2014
WILDCAT CONCRETE
SERVICES, INC.

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15 AND PROJECT NO. 2013-16
BID #14-F-0006

TABLE OF CONTENTS

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006
NOTICE TO CONTRACTORS

Notice is hereby given that sealed proposals for the performance of the contract above noted will be received in the Office of the Douglas County Clerk until 3:00 P.M., Thursday, March 20, 2014, and then publicly opened in the Courthouse, 1100 Massachusetts Street, Lawrence, Kansas.

Project No. 2013-15 & Project No. 2013-16 Includes deck repairs, machine preparation, silica fume overlay, asphalt approach transitions and temporary traffic control for Bridge #11.00N-16.40E over Coal Creek and Bridge #11.72N-17.50E over the Wakarusa River.

All bids are submitted on forms obtainable at the Office of the Director of Public Works and County Engineer, 1242 Massachusetts Street, Lawrence, Kansas or Demand Star @ www.demandstar.com, and are open for public inspection. Proposals shall be submitted in sealed envelopes, addressed to the Office of the County Clerk, Courthouse, 1100 Massachusetts, Lawrence, Kansas, upon which is clearly written or printed "Proposal for Douglas County Project No. 2013-15 & Project No. 2013-16", and the name and address of the bidder. Any bids received after the closing time will be returned unopened.

Copies of the Contract Documents, Plans and Specifications are available from the Office of the Director of Public Works and County Engineer of Douglas County, Kansas. A Twenty-Five Dollar ($25.00) non-refundable deposit is required per set, which includes one half size set of plans and a copy of the contract documents and specifications. The contract documents, plans and specifications become the property of the prospective bidder and are not returnable. Copies of the project drawings and specifications are on file and open for public inspection at the Office of the County Engineer.

All bids must be accompanied by a CERTIFIED CHECK, CASHIER'S CHECK or a BID BOND for not less than Five Percent (5%) of the base bid as a guarantee that if awarded the Contract, the bidder will enter into a Contract and give bond as required. Said check or bond shall be made payable to the Board of County Commissioners, Douglas County, Kansas.

Contracts will be awarded only to such bidders as are on the list of Pre-Qualified Contractors for the Kansas Department of Transportation on the date established for receiving and opening of bids.

The Board of County Commissioners of Douglas County, Kansas reserve the right to reject any or all bids and to waive technicalities, and to award the contract to the bidder that the Commission deems best suited to accomplish the work.

DOUGLAS COUNTY PUBLIC WORKS
Keith A. Browning, P.E.
Director of Public Works
Date: 02/24/2014

Publication Dates: Thursday, February 27, 2014
Sunday, March 9, 2014

cc:
Lawrence Journal World
Douglas County Commission
Public Works Accounting
Douglas County Clerk
Douglas County Administrator
Douglas County Purchasing
Douglas County Shop

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

INFORMATION FOR BIDDERS

1. Proposals must be submitted on duly executed copy of the Proposal Forms obtained at the Office of the Director of Public Works, 1242 Massachusetts Street, Lawrence, Kansas or Demand Star.

2. Proposals must be in sealed envelopes, addressed to the Office of the County Clerk, Courthouse, Lawrence, Kansas, upon which is clearly written, or printed, "Proposal for Douglas County Project No. 2013-15 & Project No. 2013-16" and the name and address of the bidder.

3. Each bidder shall state in his Proposal, his name, place of residence and his exact post office address, and the names and addresses of all persons or parties interested with him therein. Anyone signing a Proposal as an agent for another must file, with the Proposal, acceptable evidence of his authority to do so.

4. Each bidder is required to deposit with his Proposal a Certified Check, Cashier's Check or Bid Bond in the amount of five percent (5%) of the base bid. The above required deposit will serve as a guarantee that the bidder will file all bonds required and enter into the Contract, should it be awarded to him, according to the terms of his bid, within twenty-one (21) days after the certification of the award. Should the Contractor fail to file approved surety bonds or enter into Contract with Douglas County, Kansas, the bid security shall be forfeited as liquidated damages, and the money realized therefrom turned into the County Treasury.

5. Contracts will be let only to such bidders as are on the list of Pre-Qualified Contractors for the Kansas Department of Transportation on the date established for receiving and opening of bids.

6. Bidders must show their unit prices, make extensions based on the unit price bid for each item and total the bid for all items.

7. In the event any discrepancy occurs between the unit prices and the gross sum bid, the unit price shall apply.

8. Proposals must be signed.

9. Failure to comply with one or all of the above stated requirements will be considered sufficient grounds for rejection of the Proposal.

10. The winning bidder shall, within twenty-one (21) days of the Award of the Contract, file an approved Statutory Bond and an approved Performance and Maintenance Bond in an amount equal to the total bid.

11. No individual award will be made for each project number (2013-15 & 2013-16) per Std. Spec. 102.5(b).

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

SPECIFICATIONS

THE STANDARD SPECIFICATIONS FOR STATE ROAD AND BRIDGE CONSTRUCTION OF THE KANSAS DEPARTMENT OF TRANSPORTATION, EDITION OF 2007, shall be the Specifications for this Contract except the Sections and Articles which shall be deleted from the STANDARD SPECIFICATIONS and shall be revised as hereinafter shown.

DIVISION 100
GENERAL CLAUSES AND COVENANTS
Section 101.3

DEFINITIONS

BID BOND – DELETE item and ADD – The approved form of security, executed by the bidder and his surety or sureties, guaranteeing the execution of a satisfactory contract and the filing of an acceptable contract bond if the bidder's offer is accepted. The bid bond shall be a Certified Check, Cashier's Check or Bid Bond in the amount of five percent (5%) of the base bid. Said check or bond shall be made payable to the Board of County Commissioners, Douglas County, Kansas.

CONTRACT - DELETE item and ADD - The written agreement between the Board of County Commissioners of Douglas County, Kansas, and the Contractor setting forth the obligations of the parties thereunder, including, but not limited to, the performance of the work, the furnishing of labor and materials, and the basis of payment.

The Contract shall include the Contract Documents, which shall include the Proposal, Plans, Specifications, Contract Drawings, Supplemental Specifications, Special Provisions, Contract, Performance and Maintenance Bond, and the Statutory Bond, and also any change orders and agreements that are required to complete the construction of the work in an acceptable manner, including authorized extensions thereof, all of which constitute one instrument.

CONTRACT BOND - DELETE item and ADD - The Statutory Bond and the Performance and Maintenance Bond executed by the Contractor and his Surety, guaranteeing execution of the Contract and all Supplemental Agreements pertaining thereto and the payment of all legal debts pertaining to the construction of the Project.

DEPARTMENT - ADD - Douglas County, Kansas, represented by its Board of County Commissioners.

ENGINEER - DELETE item and ADD - Douglas County, Kansas, or the Director of Public Works of Douglas County, Kansas, acting directly or through his authorized representatives on behalf of Douglas County, Kansas.

LABORATORY - ADD - The testing laboratory designated by the Engineer.

RETAINAGE – ADD – From the grand total of the work completed as estimated by the Engineer, there shall be deducted five (5) percent to be retained by the County as required by KSA 68-1120 until full and satisfactory completion of the Contract, Specifications and Contract Documents and the Engineer shall certify the balance to the Commission for payment; except that no amount less than Five Hundred Dollars ($500.00) will be paid unless the total amount of the Contract remaining unpaid is less than Five Hundred Dollars ($500.00).

SECRETARY - DELETE item and ADD - COUNTY - Douglas County, Kansas, represented by its Board of County Commissioners.

STATE - DELETE item and ADD - COUNTY - Douglas County, Kansas represented by its Board of County Commissioners.

Section 102

BIDDING REQUIREMENTS AND CONDITIONS

102.1 CONSTRUCTION BULLETIN (ADVERTISEMENT), DELETE item and ADD – Douglas County will publish a Notice to Contractor's to notify prospective Contractors of a letting. This notice describes the contemplated work, informs the Contractor how to obtain Bidding Proposal Forms, identifies the location of plans and specifications, identifies the time and place for receiving bids, and reserves Douglas County's right to reject bids. All proposal blanks shall be obtained by prequalified bidders from the Office of the Director of Public Works of Douglas County, 1242 Massachusetts, Lawrence, Kansas. Proposal forms will be issued up to, but not after the close of business on the day preceding the opening of bids.

102.2(a) Prequalification Requirements. - DELETE the first sentence beginning with "Before...." and ending with "....work" and ADD - Bidders shall be prequalified for the type and magnitude of work covered by this Contract with the Kansas Department of Transportation as of the date established for receiving and opening of bids and shall give signed permission, if requested by the Engineer, to Douglas County, Kansas, to obtain the bidder's qualification from the Kansas Department of Transportation. Bidders will be classified under one or more of the following classifications:

102.11 BID BONDS - DELETE item and ADD - No Proposal will be accepted unless accompanied by a certified check, cashier's check or a bid bond in the amount of five percent (5%) of the base bid and made payable to the Board of County Commissioners, Douglas County, Kansas. The full amount of the proposed guaranty shall be forfeited to the County in liquidation of damages sustained in the event the bidder (or bidders) fail to execute a satisfactory Contract and file Contract Bonds within twenty-one (21) days after the notice of the award of Contract.

The Guarantees of the two (2) lowest responsible bidders shall remain in full force until such time as the execution of a Contract has been completed by the successful bidder and satisfactory Contract Bonds have been furnished. The Guarantees will be returned after the above has been accomplished.

102.12 SUBMITTING PROPOSALS - DELETE item and ADD - Each Proposal must be submitted on forms obtainable at the Office of the Director of Public Works, 1242 Massachusetts, Lawrence, Kansas, and must be submitted in sealed envelopes, addressed to the Office of the County Clerk, Courthouse, Lawrence, Kansas, 66044, upon which is clearly written or printed "Proposal for Douglas County Project No. 2013-15 & Project No. 2013-16", and the name and address of the bidder. When a Proposal is sent by mail, the above mentioned envelope shall be enclosed in another envelope addressed to the County Clerk, Courthouse, Lawrence, Kansas. All Proposals shall be filed prior to the time and at the place specified in the Notice to Contractors. Proposals received after the stated time for filing will be returned to the bidders unopened. Faxed bids will not be accepted. Douglas County is not responsible for lost or misdirected bids, whether lost or misdirected by the postal or courier service of the bidder or the Douglas County mail room.

102.13 WITHDRAWING PROPOSALS BEFORE THE LETTING - DELETE item and ADD - A Proposal may be withdrawn after it has been delivered to the Office of the County Clerk, Courthouse, Lawrence, Kansas, by a letter or by written request of the bidder or his authorized representative in person, provided the request is in the hands of the County Clerk or Board of County Commissioners before the stipulated time for the opening of the Proposals.

102.14 REVISING PROPOSALS – DELETE item and ADD -A withdrawn Proposal may be corrected or altered in person by the bidder or his authorized representative and resubmitted before the stipulated time for opening of the Proposals.

Proposals cannot be altered or corrected by wire or letter.

Section 103

AWARD AND EXECUTION OF CONTRACT

103.3 CONTRACT BOND REQUIREMENTS - DELETE item and ADD - The successful bidder before entering into a Contract and within twenty-one (21) days after notice of the award of the Contract, shall execute a Statutory Bond and a Performance and Maintenance Bond in the form prescribed by the County and in the penal sum of the amount of the Contract, with a Surety to be approved by the County. The Statutory Bond and the Performance and Maintenance Bond shall be conditioned upon the faithful performance of the Contract and the payment of all indebtedness incurred for all labor, materials and supplies furnished therefore. The Bonds must be kept in full force for the time required by law and, if longer, during the applicable warranty periods. In the event the Surety or Bonding Company fails or becomes financially insolvent, then the Contractor shall, within five (5) business days of such failure or insolvency, file new and sufficient bonds in the amount designated by the County.

103.4 (a) EXECUTING THE CONTRACT - DELETE this section and ADD - The successful bidder shall furnish satisfactory Bonds, certificate(s) of insurance, and sign the contract within twenty-one (21) days after notice of the award of Contract.

103.5 FAILING TO EXECUTE THE CONTRACT - DELETE item and ADD - The failure of the successful bidder to execute a Contract and file Contract Bonds within twenty-one (21) days from the date of the notice of the award shall, at the option of the County, be just cause for the annulment of the award and for the forfeiture of the proposal guaranty to the County, not as a penalty but in liquidation damages sustained through delay.

In the event that the County opts to annul the award, the Contract may be reawarded to the next lowest responsible bidder, or Proposals may again be received at some later date.

Section 109

MEASUREMENT AND PAYMENT

109.2 SCOPE OF PAYMENT – ADD the following paragraph 109.2(f) RETAINAGE –: From the grand total of the work completed as estimated by the Engineer, there shall be deducted five (5) percent to be retained by the County as required by KSA 68-1120 until full and satisfactory completion of the Contract, Specifications and Contract Documents and the Engineer shall certify the balance to the Commission for payment; except that no amount less than Five Hundred ($500.00) will be paid unless the total amount of the Contract remaining unpaid is less than Five Hundred Dollars ($500.00).

109.5 PROGRESS PAYMENTS, DELETE the last sentence of subsection109.5(a) "Work Accomplished" and replace with the following – "The Engineer may withhold from progress payments, liquidated damages, reimbursement for remedial work under subsection 105.5f., excess costs for breach of contract, final cleanup work expenses, five (5) percent contract retainage as required by KSA 68-1120, and other deducts the Contract Documents specify.

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

TO THE BOARD OF COUNTY COMMISSIONERS OF
DOUGLAS COUNTY, KANSAS
COURTHOUSE
LAWRENCE, KANSAS 66044

1. Proposal of WILDCAT CONCRETE SERVICES, INC for the performance of "Douglas County Project No. 2013-15 & Project No. 2013-16", in Douglas County, Kansas, by the construction of the work as described in the specifications and contract documents for the above mentioned project as set forth in the "Schedule of Prices".

2. The undersigned agrees to execute a contract for the proposed work within twenty-one (21) days after notice of the award of the Contract and to complete the work, if this proposal is accepted, as stated in Special Provision 07-DG-201. The earliest anticipated date for the "Notice to Proceed" is April 14, 2014.

3. In conformity with Article 108.8 of the Specifications, the liquidated damages for this Contract shall be as stated in Table 108-1; TABLE OF LIQUIDATED DAMAGES.

4. In submitting this bid, the undersigned declares that he is the only person interested in said bid; that is made without any connection with any person or persons making another bid for the same Contract; that is in all respects fair and without collusion, fraud or misrepresentation.

5. The undersigned further declares that he has carefully examined the specifications, form of contract, and special provisions, and that he has inspected the actual location of the work, together with the local sources of supplies, and has satisfied himself as to all quantities and conditions, and understands that in signing this proposal he waives all right to plead any misunderstanding regarding the same.

6. The undersigned acknowledges receipt of the following Addenda:

Addendum No.	Dated
#1	3-4-14

WILDCAT CONCRETE SERVICES, INC.
Name of Organization

By: Stuart R Johnson

DOUGLAS COUNTY PUBLIC WORKS
1242 Massachusetts Street
Lawrence, KS 66044-3350
(785) 832-5293 Fax (785) 841-0943
dgcopubw@douglas-county.com
www.douglas-county.com

Keith A. Browning, P.E.
Director of Public Works/County Engineer

MARCH 4, 2014

SPECIFICATIONS AND CONTRACT DOCUMENTS
FOR
DOUGLAS COUNTY PROJECT NO. 2013-15 AND 2013-16
BID NO. 14-F-0006

ADDENDUM NO.1

This addendum is issued to verify that the above named plans and specifications are modified and/or supplemented, as noted herein, and is, from the above date an integral part of the Contract Documents.

REMOVE AND REPLACE SP-1 SCHEDULE OF PRICES OF THE CONTRACT WITH SP-1 **REVISED SCHEDULE OF PRICES**

The set prices for the following were added:

Material for Silica Fume Overlay (Set Price)	**$175.00/C.Y.**
Reinforcing Steel (Gr. 60) (Repair) (Set Price)	**$3.00/Lbs.**

This addendum is hereby made a part of the bid documents to the same extent as though contained in the original documents.

The Contractor shall hereby acknowledge receipt of the above referenced addendum on the Proposal (P-1) page of the original set of the contract documents then complete and attach this addendum to the contract prior to submittal.

Keith A. Browning
Keith A. Browning, P.E.
Director of Public Works

WILDCAT CONCRETE SERVICES, INC.
Name of Organization

By:

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15 & PROJECT NO. 2013-16
BID #14-F-0006

REVISED SCHEDULE OF PRICES

SPEC. NO.	BIDDING ITEMS BRIDGE NO. 11.00N-16.40E	APPROX QTYS.	UNIT	UNIT PRICE	AMOUNT	
612	Milling	556	S.Y.	6.00	3,336.00	✓
611/Spec Prov	HMA – Commercial Grade (Class A)	66	Ton	120.00	7,920.00	✓
611/Spec Prov	HMA – Commercial Grade (Class A) (Patching)	20	Ton	175.00	3,500.00	✓
732	Machine Preparation (0.75")	678	S.Y.	25.00	16,950.00	✓
731	Area Prepared for Patching	270	S.Y.	225.00	60,750.00	✓
731	Area Prepared for Patching (Full Depth)	5	S.Y.	400.00	2,000.00	✓
717/Spec Prov	Silica Fume Overlay (1.5")	678	S.Y.	40.00	27,120.00	✓
717/Spec Prov	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	
731	Reinforcing Steel (Gr. 60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	
801	Mobilization	1	L.S.	15,000.00	15,000.00	
805	Traffic Control	1	L.S.	5,000.00	5,000.00	

TOTAL $ 141,754.00 ✓

SPEC. NO.	BIDDING ITEMS BRIDGE NO. 11.72N-17.50E	APPROX QTYS.	UNIT	UNIT PRICE	AMOUNT	
612	Milling	553	S.Y.	6.00	3,318.00	✓
611/Spec Prov	HMA – Commercial Grade (Class A)	63	Ton	120.00	7,560.00	✓
611/Spec Prov	HMA – Commercial Grade (Class A) (Patching)	20	Ton	175.00	3,500.00	✓
732	Machine Preparation (0.75")	711	S.Y.	25.00	17,775.00	✓
731	Area Prepared for Patching	142	S.Y.	225.00	31,950.00	✓
731	Area Prepared for Patching (Full Depth)	5	S.Y.	400.00	2,000.00	✓
717/Spec Prov	Silica Fume Overlay (1.5")	711	S.Y.	40.00	28,440.00	✓
717/Spec Prov	Material for Silica Fume Overlay (Set Price)	1	C.Y.	$175.00	$175.00	
731	Reinforcing Steel (Gr. 60)(Repair)(Set Price)	1	Lbs.	$3.00	$3.00	
801	Mobilization	1	L.S.	15,000.00	15,000.00	
805	Traffic Control	1	L.S.	5,000.00	5,000.00	

TOTAL $ 114,721.00 ✓

GRAND TOTAL $ 256,475.00 ✓

NOTE: Bidder shall extend all items and total bid.

WILDCAT CONCRETE SERVICES, INC.
CONTRACTOR

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15 & PROJECT NO. 2013-16
BID #14-F-0006

SCHEDULE OF PRICES

SPEC. NO.	BIDDING ITEMS BRIDGE NO. 11.00N-16.40E	APPROX QTYS.	UNIT	UNIT PRICE	AMOUNT
612	Milling	556	S.Y.		
611/Spec Prov	HMA – Commercial Grade (Class A)	66	Ton		
611/Spec Prov	HMA – Commercial Grade (Class A) (Patching)	20	Ton		
732	Machine Preparation (0.75”)	678	S.Y.		
731	Area Prepared for Patching	270	S.Y.		
731	Area Prepared for Patching (Full Depth)	5	S.Y.		
717/Spec Prov	Silica Fume Overlay (1.5”)	678	S.Y.		
717/Spec Prov	Material for Silica Fume Overlay (Set Price)	1	C.Y.		
731	Reinforcing Steel (Gr. 60)(Repair)(Set Price)	1	Lbs.		
801	Mobilization	1	L.S.		
805	Traffic Control	1	L.S.		

TOTAL $________________

SPEC. NO.	BIDDING ITEMS BRIDGE NO. 11.72N-17.50E	APPROX QTYS.	UNIT	UNIT PRICE	AMOUNT
612	Milling	553	S.Y.		
611/Spec Prov	HMA – Commercial Grade (Class A)	63	Ton		
611/Spec Prov	HMA – Commercial Grade (Class A) (Patching)	20	Ton		
732	Machine Preparation (0.75”)	711	S.Y.		
731	Area Prepared for Patching	142	S.Y.		
731	Area Prepared for Patching (Full Depth)	5	S.Y.		
717/Spec Prov	Silica Fume Overlay (1.5”)	711	S.Y.		
717/Spec Prov	Material for Silica Fume Overlay (Set Price)	1	C.Y.		
731	Reinforcing Steel (Gr. 60)(Repair)(Set Price)	1	Lbs.		
801	Mobilization	1	L.S.		
805	Traffic Control	1	L.S.		

TOTAL $________________

GRAND TOTAL $ ________________

NOTE: Bidder shall extend all items and total bid.

____
CONTRACTOR

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

CONTRACT

THIS CONTRACT, made and entered into this ____________ day of ________________________, 2014, by and between the BOARD OF COUNTY COMMISSIONERS OF DOUGLAS COUNTY, KANSAS, Party of the First Part, hereinafter referred to as the COUNTY, and ________________________________ ____________________________________, Party of the Second Part, hereinafter referred to as the CONTRACTOR.

WITNESSETH:

Article 1: It is hereby mutually agreed, that for and in consideration of the sum or sums to be paid the Contractor by the County as set forth in the General Clauses, the said Contractor shall furnish all labor, equipment, accessories and materials (except materials salvaged or otherwise furnished as specified) and shall perform all work necessary to construct and complete the improvements in a good, substantial and workmanlike manner, ready for use, and in strict accordance with the Specifications and Contract Drawings as approved and filed pursuant to law in the Office of the County Clerk of Douglas County, Kansas.

Article 2: It is hereby further agreed, that, in consideration of the faithful performance of the work by the Contractor, the County shall pay the Contractor the sum or sums due him by reason of said faithful performance of the work, at stated intervals and in amounts certified by the Engineer, in accordance with the Specifications and Contract Documents, and set forth in the Proposal as accepted by the County, subject to compliance with K.S.A 68, Article 11.

Article 3: It is hereby further agreed that Contractor will, for a period of twelve (12) months following the County's acceptance of the Contractor's work, at the request of County, correct any defects in the work due to faulty or defective materials or workmanship, without additional cost to the County; provided that neither final payment by the County nor the acceptance of the Contractor's work shall relieve Contractor, or its surety under the Performance and Maintenance Bond, from such obligation to cure any such defects.

Article 4: It is hereby further agreed that, at the completion of the work, and its acceptance by the County, all sums due the Contractor by reason of his faithful completion of the work, taking into consideration additions to or deductions from the contract price by reasons of alterations or modifications of the original contract or by reasons of "Force Account" work authorized under the Contract in accordance with the provisions of the General Clauses, will be paid the Contractor by the County within sixty (60) days after said completion and acceptance.

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

CONTRACT (continued)

Article 5: It is hereby further agreed, that the "he" or "him" wherever used herein as referring to the Contractor shall be deemed to referring to the Contractor, his-her-theirs heirs, executors, administrators, successors, or assigns.

Article 6: It is hereby further agreed that any reference herein to the "Contract Documents" shall include all "Contract Documents" as specifically set out in the Specifications and are hereby made a part of this Contract as fully as if set out in length herein.

IN WITNESS WHEREOF, the Party of the First Part and Party of the Second Part, respectively, have caused this agreement to be duly executed the day and year first hereinwritten, in quadruplicate, all copies of which to all intents and purposes shall be considered as the original.

ATTEST:	BOARD OF COUNTY COMMISSIONERS OF DOUGLAS COUNTY, KANSAS
______________________ County Clerk	______________________ Chairman
______________________ Date	______________________ Commissioner
	______________________ Commissioner
Approved as to Legality:	
______________________ Douglas County Counselor	______________________ Name of Organization
______________________ Date	By: ______________________
	______________________ Title of Signature

BOND NO. ___________

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

STATUTORY (PAYMENT) BOND

KNOW ALL MEN BY THESE PRESENTS THAT:

We, ____, as Principal, and ____, a surety company duly authorized to do business in the State of Kansas, as Surety, are held and firmly bound unto the State of Kansas in the penal sum of ________________________ ________________________ Dollars ($____________________) (the current amount of the contract price between Principal and Owner) lawful money of the United States of America, for the payment of which sum well and truly to be made, bind ourselves and our respective heirs, executors, administrators, successors, and assigns, jointly and severally, firmly by these presents.

THE CONDITION OF THE FOREGOING OBLIGATION IS SUCH THAT, WHEREAS, the Principal has on the _____ day of ______________________, 20___, entered into a written Agreement with the Board of County Commissioners of Douglas County, Kansas, hereinafter called the Owner, for furnishing labor, equipment, material, and supplies used or consumed in connection with the installation, construction of, or in making such improvements, equipment, and services described in said Agreement, all in accordance with the plans, specifications and other Contract Documents described therein and as supplemented and otherwise changed during the project (the "Undertaking"). The Agreement (including but not limited to the plans, specifications and other Contract Documents) is by reference made a part hereof, and is hereinafter called the Contract.

NOW, THEREFORE, if the Principal or any Subcontractor or Subcontractors of the Principal shall pay all indebtedness incurred for the Undertaking as required under the Contract, then this obligation shall become null and void; otherwise, it shall remain in full force and effect. If the Principal or any Subcontractor or Subcontractors of the Principal fails to duly pay all indebtedness incurred for the Undertaking as required under the Contract, then the Surety shall pay the same in any amount not exceeding the amount of this obligation, together with any interest and attorneys' fees as provided by law.

PROVIDED, FURTHER, that the Surety hereby stipulates and agrees, for value received, that no change, extension of time, modification, supplement, alteration or addition to the undertakings, covenants, terms or conditions of the Contract or the Undertaking, shall in any way affect its obligations on this bond. The Surety does hereby waive notice of any change, extension of time, modification, supplement, alteration or addition to the terms or conditions of the Contract or Undertaking. The Surety stipulates and agrees that the penal sum of this bond shall be automatically increased or decreased by any change order(s) to the Contract as approved by the Owner.

Nonpayment of the bond premium will not invalidate this bond nor shall the Owner be obligated for the payment of any bond premium.

The Surety and Principal agree that any persons interested shall have a direct right of action hereunder against the Principal and Surety.

IN WITNESS WHEREOF, the Principal and Surety have caused this bond to be duly signed this ____ day of __________________, 20___.

____
Principal

By____

____
(Official Title)

____
Surety Company

By:____________________________________
(Attorney-In-Fact)

By:_____________________________________
(Kansas Agent)

(A certified copy of the Attorney-in-Fact's Power of Attorney from the Surety, to include the date and amount of the bond, must be attached to this bond).

Filed with the Clerk of the District Court of Douglas County, Kansas, this _______ day of ______________________, 20_____.

____
Clerk of the District Court

BOND NO. ____________________

DOUGLAS COUNTY, KANSAS
PROJECT NO. 2013-15
AND
PROJECT NO. 2013-16
BID #14-F-0006

PERFORMANCE BOND

KNOW ALL MEN BY THESE PRESENTS THAT:

We, ____, as Principal, and ____, a surety company duly authorized to do business in the State of Kansas, as Surety, are held and firmly bound unto the Board of County Commissioners of Douglas County, Kansas, as Obligee, in the penal sum of ____ Dollars ($____________________) (the current amount of the contract price between Principal and Obligee), lawful money of the United States of America, for the payment of which sum well and truly to be made, bind ourselves, and our respective heirs, executors, administrators, successors, and assigns, jointly and severally, firmly by these presents.

THE CONDITION OF THE FOREGOING OBLIGATION IS SUCH THAT, WHEREAS, the Principal has, on ______________________, 20____, entered into a written Agreement with the Obligee for furnishing labor, equipment, material, and supplies in connection with the installation, construction of or in making such improvements, equipment, and services described in said Agreement, all in accordance with the plans, specifications and other Contract Documents described therein and as supplemented and otherwise changed during the project. The Agreement (including but not limited to the plans, specifications and other Contract Documents) is by reference made a part hereof, and is hereinafter called the Contract.

NOW, THEREFORE, if the Principal shall and will, in all particulars, well, duly and faithfully observe, perform and abide by each and every covenant, condition, obligation and part of the Contract, according to the true intent and meaning in each case, and hold the Obligee harmless against all claims, loss or damage which it may sustain or suffer by reason of any breach of said Contract by said Principal or by reason of any injury to persons or property occasioned by the action of said Principal or its employees, and if said Principal maintains the improvement, equipment, and service as provided for in said Contract and make good all defects in materials and workmanship as required under the Contract, then this obligation shall be and become null and void; otherwise, it shall remain in full force and effect. Whenever the Principal is, and is declared by the Obligee to be, in default under the Contract, the Surety shall remedy the default at its expense by promptly (a) completing the Contract in accordance with its terms and conditions, through its agents or independent contractors; or (b) obtaining a bid or bids for completing the Contract in accordance with its terms and conditions, and, upon determination by the Obligee of the lowest and best bid, arrange for an agreement between such bidder and the Obligee, secured by payment and performance bonds, and pay to Obligee the final cost of such agreements less the balance of the Contract Price, but not exceeding, including other costs and damages for which the Surety may be liable hereunder, the amount set forth in the first paragraph hereof as the same may be increased by change order(s) to the Contract as approved by the Obligee; or (c) work out such other arrangements as are accepted by Obligee in writing. The term "balance of the Contract Price," as used herein, shall mean the total amount payable by the Obligee to the Principal under the Contract, and any amendments thereto, less the amount paid by the Obilgee to the Principal.

PROVIDED, FURTHER, that the Surety hereby stipulates and agrees, for value received, that no change, extension of time, modification, supplement, alteration or addition to the undertakings, covenants, terms or conditions of the Contract or the Undertaking, shall in any way affect its obligations on this bond. The Surety does hereby waive notice of any change, extension of time, modification, supplement, alteration or addition to the terms or conditions of the Contract or Undertaking. The Surety stipulates and agrees that the penal sum of this bond shall be automatically increased or decreased by any change order(s) to the Contract as approved by the Obligee. Principal and Surety further stipulate and agree that acceptance, approval or certification of completion of work under the Contract and/or payment (final or otherwise) by Obligee shall not relieve the Principal or Surety from any liability for any failure to fully perform the Contract or any other obligation on this bond.

Nonpayment of the bond premium will not invalidate this bond nor shall the Obligee be obligated for the payment of any bond premium.

IN WITNESS WHEREOF, the Principal and Surety have caused this bond to be duly signed this ____ day of __________________, 20___.

____
Principal

By______________________________________

____
(Official Title)

____
Surety Company

By:______________________________________
(Attorney-In-Fact)

By:______________________________________
(Kansas Agent)

(A certified copy of the Attorney-in-Fact's Power of Attorney from the Surety, to include the date and amount of the bond, must be attached to this bond).
Sufficiency of the Bond Approved by:

____
Chairperson of Board of County Commissioners

Date: ________________

Form and Amount of Bond Approved By:

____
County Counselor

Date: ________________

NOTE:

1. Date of bond must not be prior to date of Agreement.
2. If Principal is a partnership, all partners should execute bond.
3. Surety companies executing bonds must appear on the U.S. Department of the Treasury's most current listing of approved sureties (Department Circular 570, as amended), and be authorized to transact business in the State of Kansas.
4. Accompany this bond with Attorney-in-Fact's authority from the Surety certified to include the date of the bond.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

SALES TAX EXEMPTION

In accordance with the provisions of K.S.A. 79-3606 (b), this Douglas County Project qualifies for Sales Tax Exemption. A sales tax exemption certificate number will be furnished to the Contractor following award of the Contract. The Contractor shall furnish to the Engineer copies of invoices on all materials incorporated in this project.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

DOUGLAS COUNTY
CONTRACTUAL PROVISIONS ATTACHMENT

(a) Terms Herein Controlling Provisions: It is expressly agreed that the terms of each and every provision in this attachment shall prevail and control over the terms of any other conflicting position in any other document relating to and a part of the contract in which this attachment is incorporated. As used herein, the term "Douglas County" shall refer to Douglas County and any of its agencies, offices, and departments entering into the contract.

(b) Agreement With Kansas Law: All contractual agreements shall be subject to, governed by, and construed according to the laws of the State of Kansas.

(c) Termination Due to Lack of Funding Appropriation: If, in the judgment of the County Administrator, sufficient funds are not appropriated to continue the function performed in this agreement and for the payment of the charges hereunder, Douglas County may terminate this agreement at the end of its current fiscal year. Douglas County agrees to give written notice of termination to vendor/contractor at least 30 days prior to the end of its current fiscal year, and shall give such notice for a greater period prior to the end of such fiscal year as may be provided in the contract, except that such notice shall not be required prior to 90 days before the end of such fiscal year. Vendor/contractor shall have the right, at the end of such fiscal year, to take possession of any unpaid equipment provided Douglas County under the contract. Douglas County will pay to the vendor/contractor all regular contractual payments incurred through the end of such fiscal year, plus contractual charges incidental to the return of any such equipment. Upon termination, of the agreement by Douglas County, title to any such unpaid equipment shall revert to vendor/contractor at the end of Douglas County's current fiscal year. The termination of the contract pursuant to this paragraph shall not cause any penalty to be charged to Douglas County or the vendor/contractor.

(d) Disclaimer of Liability: Douglas County shall not hold harmless or indemnify any vendor/contractor beyond that liability under the Kansas Tort Claims Act (K.S.A 75-6101 et seq.).

(e.) Arbitration, Payment Due, Interest, Warranties: Notwithstanding any language to the contrary, no interpretation shall be allowed to find Douglas County has agreed to binding arbitration, or the payment of damages or penalties upon the occurrence of a contingency.

Payment from Douglas County to vendor/contractor shall not be due sooner than 30 days after the delivery of an invoice from vendor/contractor to Douglas County. Further, Douglas County does not agree to pay attorney fees or late payment charges beyond those available under K.S.A. 16-201, and no provision will be given effect which attempts to exclude, modify, disclaim or otherwise attempt to limit implied warranties of merchantability and fitness for a particular purpose.

(f) Representative's Authority To Contract: By signing this contract, the representative of the vendor/contractor hereby represents that such person is duly authorized by the vendor/contractor to execute this contract on behalf of the vendor/contractor and that the vendor/contractor agrees to be bound by the provisions thereof.

(g) Responsibility For Taxes: Douglas County shall not be responsible for, nor indemnify vendor/contractor for, any federal, state, or local taxes which may be imposed or levied upon the subject matter of this contract.

(h) Anti-Discrimination Clause: The vendor/contractor agrees: (a) to comply with the Kansas Act Against Discrimination (K.S.A. 44-1001 et seq.) and the Kansas Age Discrimination in Employment Act (K.S.A. 44-1111 et seq.) and the applicable provisions of the Americans with Disabilities Act (42 U.S.C. 12101 et seq.) (ADA) and to not discriminate against any person because of race, religion, color sex, disability, national origin or ancestry, or age in the admission or access to, or treatment or employment in, its programs or activities; (b) to include in all solicitations or advertisements for employees, the phrase "equal opportunity employer"; (c) to comply with the reporting requirements set out at K.S.A. 44-1031 and K.S.A. 44-1116; (d) to include those provisions in every subcontract or purchase order so that they are binding upon such subcontractor or vendor; (e) that a failure to comply with the reporting requirements of (c) above or if the vendor/contractor is found guilty of any violation of such acts by the Kansas Human Rights Commission, such violation shall constitute a breach of contract and the contract may be cancelled, terminated or suspended, in whole or in part, by Douglas County; (f) if it is determined that the vendor/contractor has violated applicable provisions of ADA, such violation shall constitute a breach of contract and the contract may be cancelled, terminated or suspended, in whole or in part by Douglas County.

Parties to this contract understand that the provisions of this paragraph (h) (with the exception of those provisions relating to the ADA) are not applicable to a vendor/contractor who employs fewer than four employees during the term of such contract or whose contracts with Douglas County cumulatively total $5,000 or less during the fiscal year of Douglas County.

SPECIAL PROVISIONS

TO THE

STANDARD SPECIFICATIONS

EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

GENERAL DESCRIPTION:

Project No. 2013-15 & Project No. 2013-16 Includes deck repairs, machine preparation, silica fume overlay, asphalt approach transitions and temporary traffic control for Bridge #11.00N-16.40E over Coal Creek and Bridge #11.72N-17.50E over the Wakarusa River.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

PLANS: The following plans accompany and supplement the Specifications:

Sheet No.	Sheet Title
Bridge No. 11.00N – 16.40E	
1	Title Sheet
2	Pavement Details
3	Summary of Quantities and General Notes
4	Construction Layout
5	Delamination Map
6	Bridge Deck Patching and Wearing Surface Details
7-12	Traffic Control
Bridge No. 11.72N – 17.50E	
1	Title Sheet
2	Pavement Details
3	Summary of Quantities and General Notes
4	Construction Layout
5	Delamination Map
6	Bridge Deck Patching and Wearing Surface Details
7-12	Traffic Control

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

ENGINEER: For the performance of work under this Contract, Douglas County, Kansas will perform the duties of the Engineer, as defined in the Specifications and hereinafter is referred to as the Engineer.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

OPERATIONS OF OTHERS: The right is reserved by the County to have other work performed by other Contractors and to permit public utility companies and others to do work during the construction of and within the limits of or adjacent to the Project. The Contractor shall conduct his operations and cooperate with such other parties so that interference with such other work will be reduced to a minimum. The Contractor shall agree, and hereby does agree, to make no claims against the County for additional compensation due to delays or other conditions created by the operations of other such parties. Should a difference of opinion arise as to the rights of the Contractor and others working within the limits of or adjacent to the Project, the Engineer will decide as to the respective rights of the various parties involved in order to assure the completion of the work in general harmony and in a satisfactory manner and his decision shall be final and binding upon the Contractor.

To expedite the completion of the over-all Project, it will be necessary for the work under this Contract to be coordinated with the construction under other contracts and by others. As far as possible, each Contractor shall so plan and conduct his operations and dispose of his materials as not to interfere with the operations of or damage the work of others engaged upon the construction of the overall Project. The Contractor shall perform his work in proper sequence with relation to that of the other Contractors and as the Engineer may direct. Each Contractor starting work while construction under other Contracts is in progress within the limits of the Project shall begin his work at certain locations which the Engineer may designate or approve and thereafter shall prosecute the work at such locations and in such order as the Engineer may from time to time prescribe or approve.

SPECIAL PROVISIONS

TO THE

STANDARD SPECIFICATIONS

EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

INSPECTION: The Contractor shall furnish access to all parts of the Project for inspection by the Engineer or authorized representative of the Engineer. The Contractor shall notify the Engineer twenty-four (24) hours in advance of beginning work which requires inspection.

SPECIAL PROVISIONS

TO THE

STANDARD SPECIFICATIONS

EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

RIGHT-OF-WAY: The right-of-way will be available for use by the Contractor for access roads and storage space; provided that such use does not interfere with the permanent construction of the overall Project under this or any other contract and shall be subject to similar use by other Contractors working on various parts of the Project. Such use shall not impair the safety of the traveling public. Right-of-way shall be restored by the Contractor to its original condition before final payment will be made.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

SPECIFICATIONS: The bidder and/or Contractor are required to furnish his own copies of the Standard Specifications for State Road and Bridge Construction of the Kansas Department of Transportation, Edition of 2007.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

INDEMNITY PROVISION: The Contractor hereby agrees to indemnify and hold harmless the County for any liability resulting from the injury or death of any person, including Contractor's employees, arising from unsafe conditions at the work site. "Unsafe" shall mean a failure by the Contractor to adhere to any applicable federal, state or local government standards established to protect the health, safety and welfare of the Contractor's employee, other persons at the work site, and the public in general.

SPECIAL PROVISION
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications of Standard Specifications, this Special Provision shall govern.

SECTION 611

HOT MIX ASPHALT (HMA) – COMMERCIAL GRADE

SECTION 611.1 DESCRIPTION, Add the following Bid Items:

BID ITEMS	UNITS
HMA – COMMERCIAL GRADE (CLASS A) (SURFACE)	TON
HMA – COMMERCIAL GRADE (CLASS A) (PATCH)	TON

SECTION 611.2 MATERIALS, TABLE 611-1,

Change the "Reclaimed Asphalt Pavement (RAP) (max. %)" from 25% to 10% for mixes designated for surface construction and 30% for mixes designated for patching and/or asphalt base construction.

Change the Binder requirement to PG64-22.

Delete note (1) shown below table 611-1.

SPECIAL PROVISIONS
TO THE
STANDARD SPECIFICATIONS
EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications of Standard Specifications, this Special Provision shall govern.

Project Scheduling, Specified Calendar Completion Date, and Liquidated Damages:

1. The "Notice to Proceed" will be issued on April 14, 2014. A minimum of 96 hours notice is required before closing any roadway.

2. Project 2013-15 (Br. No. 11.00N-16.40E) shall be completed and opened to "unrestricted traffic" before July 1, 2014.
   Project 2013-16 (Br. No. 11.72N-17.50E) shall be completed and opened to "unrestricted traffic" on July 18, 2014.
   "Unrestricted Traffic" is defined in Section 108.4 of the Specifications.

3. No clean-up days will be allowed on Project No. 2013-15. The Contractor will be allowed 5 clean-up calendar days as per Section 108.6 & 108.4c(3).

4. Liquidated damages shall be as shown in section 108.8, (Table 108-1) of the Standard Specifications.

SPECIAL PROVISIONS

TO THE

STANDARD SPECIFICATIONS

EDITION OF 2007

NOTE: Whenever this special provision conflicts with the Plans, Supplemental Specifications or Standard Specifications, this Special Provision shall govern.

PRICE ADJUSTMENT FOR ASPHALT MATERIALS

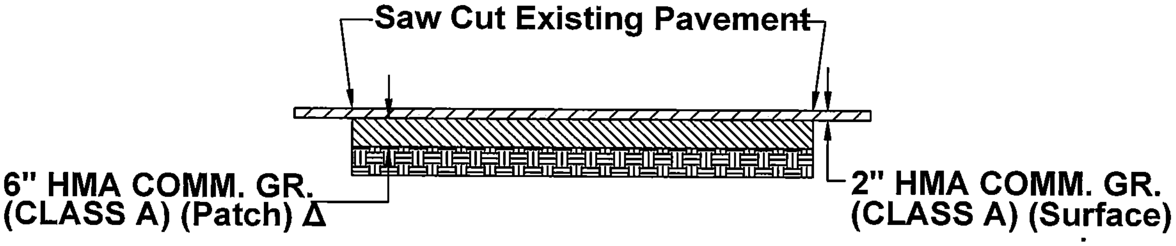
Prices quoted for asphalt material (HMA – Commercial Grade (Class A)) will be based on the Computed Monthly Asphalt Material Index in effect for March, 2014 as listed @ http:/www.ksdot.org/burconsmain/ppreq/AsphaltPriceIndex.asp. Hot mix asphalt provided/placed will be adjusted in subsequent months $0.50/ton for each $10.00 increase/decrease in the Computed Monthly Asphalt Material Index, based on the initial price index shown for March, 2014.

The adjusted unit cost will apply until all work is complete. If contract time expires, no additional increases will be allowed, but if the asphalt price decreases during this time the revised unit costs will reflect this change.

Example:

Change in Price of Asphalt Oil/Ton	Adjustment in the Bid Price of Asphalt Mat'l
$0.00 - $9.99	$0.00
$10.00 - $19.99	$0.50
$20.00 - $29.99	$1.00
$30.00 - $39.99	$1.50

HMA PAVEMENT PATCHING DETAIL



Typical **Detail for Patching**

Notes:

1. THE SUBGRADE SHALL BE THOROUGHLY AND UNIFORMLY RECOMPACTED BY HAND TAMPING AND ROLLING.

2. THE BITUMINOUS MIXTURE SHALL BE DEPOSITED IN UNIFORMLY SPREAD LAYERS NOT TO EXCEED 3" IN THICKNESS AND EACH LAYER SHALL BE THOROUGHLY COMPACTED BY A SELF PROPELLED VIBRATORY STEEL DRUM ROLLER.

3. BITUMINOUS MIX USED FOR PAVEMENT PATCHING WILL BE PAID PER TON OF ACTUAL MATERIAL PLACED AND ACCEPTED.

4. SAW CUTS WILL BE SUBSIDIARY TO HMA- COMM. GR. (CLASS A) (PATCH) CONSTRUCTION REQUIREMENTS SHALL BE AS STATED IN SECTION 833 OF THE 2007 STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION.

5. THE LOCATIONS OF BITUMINOUS PAVEMENT PATCHING WILL BE DETERMINED BY THE ENGINEER AFTER ANY MILLING OPERATIONS ARE COMPLETED.

6. EMULSIFIED ASPHALT (SS-1HP) FOR TACK IS REQUIRED ON ALL SURFACES AT PATCH LOCATIONS PRIOR TO PLACING HMA (PATCH) MATERIAL. A LIGHT COAT OF SS-1HP IS REQUIRED BETWEEN SUCCESSIVE LIFTS OF HMA (PATCH) MATERIAL. THIS WORK IS SUBSIDIARY TO HMA (PATCH).

Δ THE ACTUAL DEPTH OF HMA (PATCH) MAY BE ADJUSTED BY THE ENGINEER TO ACCOMMODATE CONDITIONS FOUND DURING CONSTRUCTION.

Douglas County Public Works
1242 Massachusetts
Lawrence, Kansas 66044

PROJECT NO.

DESIGNED BY N.P

DRAWN BY L.H.

PROJECT NAME

HMA PAVEMENT PATCHING DETAIL

SECTION 717

SILICA FUME OVERLAY

Page 700-83, Subsection 717.1 Delete the (**) from the bid item Silica Fume Overlay, and Delete "** High Early Strength".

717.1 DESCRIPTION

Construct the silica fume overlay as shown on the Contract Documents.

BID ITEMS	**UNITS**
Silica Fume Overlay (*) (**)	Square Yard
Material for Silica Fume Overlay (Set Price)	Cubic Yard
* Denotes Thickness	
**High Early Strength	

717.2 MATERIALS

Provide materials that comply with the applicable requirements.

Silica Fume Concrete	**DIVISION 400**
Precure/Finishing Aid Material	**DIVISION 1400**
Concrete Curing Materials	**DIVISION 1400**
Concrete Masonry Coating	**DIVISION 1700**

Page 700-83, Subsection 717.3 In the fourth paragraph, last sentence, Change "Vibrated Unit Weight" to "Consolidated Unit Weight"

717.3 CONSTRUCTION REQUIREMENTS

a. Equipment. Use a finishing machine consisting of a mechanical strike-off capable of providing a uniform thickness of concrete slightly above finish grade in front of an oscillating screed or screeds. The finishing machine will be inspected and approved by the Engineer before work is started on each project.

Use a minimum of 1 oscillating screed capable of consolidating the concrete by vibration to 100% of the vibrated unit weight with the following features:

- Install identical vibrators so a minimum of 1 vibrator is provided for each 5 feet of screed length;
- Bottom face a minimum of 5 inches wide with a turned up or rounded leading edge;
- Effective weight a minimum of 75 pounds for each square foot bottom face area;
- Positive control of vertical position, the angle of tilt and the shape of the crown;
- Design together with appurtenant equipment to obtain positive machine screeding of the plastic concrete as close as practical to the face of the existing curb line;
- Length sufficient to uniformly strike-off and consolidate the width of the lane to be paved;
- Forward and reverse motion under positive control;
- Supporting rails which are fully adjustable (not shimmed) to obtain the correct profile, unless otherwise approved by the Engineer. Provide supports which are sufficiently rigid and do not deflect under the weight of the machine. Anchor the supporting rails to provide horizontal and vertical stability; and
- Equip to travel on the completed lane when placing concrete in a lane abutting a previously completed lane.

Manufacturer's specifications or certification may be used as verification of the oscillating screed requirements.

A drum roller equipped to perform all functions outlined for the oscillating screed above, may be used for finishing the overlay concrete in lieu of an oscillating screed. Equip the drum roller to vibrate by either a factory or field adaptation. The drum roller must be able to compact the concrete to a minimum of 100% of the vibrated unit weight.

Provide an overall combination of labor and equipment with the capability for proportioning, mixing, placing and finishing new concrete at the following minimum rates shown in **TABLE 717-1**.

TABLE 717-1: SILICA FUME PRODUCTION REQUIREMENTS	
Total Placed Surface Area per Bridge (Square Yards)	Minimum Cubic Yards per Hour
0-328	1.0
329-492	1.5
493-656	2.0
Over 656	2.5

b. Preparation of Surface. Prior to final preparation for placement of new concrete, sand or shot blast the surface followed by an air blast to the bottom 3 inches of hubguard, and edges against which new concrete is to be placed to remove all dirt, oil and other foreign material, as well as any unsound concrete, laitance and curing material from the surface. Wet sand blasting may be used only with approval of the Engineer. It is desired that the surface be roughened by the sand or shot blast to provide satisfactory bond with the surfacing concrete. Protect metal floor drains and areas of the curb or railing above the proposed surface from the sand or shot blast.

Check the finish machine clearance above the prepared surface before concrete is placed to obtain the thickness specified in the Contract Documents.

A minimum of 2 hours before the placing of the concrete overlay, use clean water to thoroughly wet any concrete surfaces to which the concrete is to bond against. Blow or broom away all free water immediately ahead of the placing operation. Bonding surfaces should be maintained in a damp condition with no free water.

Page 700-84, Subsection 717.3c. Delete the ninth paragraph (Manipulate, ...) and replace with the following:

> Manipulate, mechanically strike off and mechanically consolidate new concrete to a minimum of 98% of the consolidated unit weight and screed to final grade. Float and straight edge the wearing surface so the finished surface is at the cross-section shown in the Contract Documents. In irregular areas or along the curb where the finished screed does not reach, hand tamp with a 6" x 6" metal plate device to assist in consolidation and bonding of the concrete. When concrete for partial depth patches is placed with the overlay, apply additional vibration or hand tamping the patch areas to assist in consolidation and bonding of the concrete.

c. Placing and Finishing Concrete. The elapsed time between depositing the concrete on the floor and final screeding may not exceed 10 minutes, unless otherwise authorized by the Engineer.

Placing of silica fume concrete is prohibited when conditions on the bridge deck are such that the evaporation rate is estimated to equal or exceed 0.2 pounds per square foot per hour, or is predicted to exceed that rate during the course of the placement, unless corrective measures listed below are taken to reduce the evaporation rate to below 0.2 pounds per square foot per hour.

Just prior to and at least once per hour during placement of the concrete, the Engineer will measure and record the air temperature, concrete temperature, wind speed and humidity on the bridge deck. The Engineer will take the air temperature, wind and humidity measurements approximately 12 inches above the surface of the deck. With this information, the Engineer will determine the evaporation rate by using KDOT software or by using **FIGURE 710-1** (Figure 2.1.5 from the American Concrete Institute Manual of Concrete Practice 305R, Chapter 2).

When the evaporation rate is equal to or above 0.2 lb/ft^2/hr, take actions (such as cooling the concrete, installing wind breaks, sun screens etc.) to create and maintain an evaporation rate less than 0.2 lb/ft^2/hr on the entire area where the silica fume is to be placed.

Accomplish fogging by using high pressure equipment that generates a minimum of 1200 psi at 2.2 gpm, or with low pressure equipment having nozzles capable of supplying a maximum flow rate of 1.6 gpm. In either case, the fog spray is produced from nozzles which atomize the droplets, and are capable of keeping a large surface area damp without depositing noticeable water.

The evaporation rate will be rechecked with the measures in place, using the procedures outlined above.

Place and fasten the screed rails in position to obtain finished concrete at the required profile. Place the supporting rails upon which the finishing machine travels outside the area to be concreted. A hold-down device shot into concrete is prohibited, unless the concrete is to be subsequently overlaid. Hold-down devices of other types leaving holes in exposed areas will be approved provided the holes remaining are grouted full. Methods for anchoring and supporting the rails and the concrete placing procedure require approval by the Engineer.

Locate longitudinal joints along lane lines, or as approved by the Engineer. Keep the joints clear of wheel paths as much as practical.

Manipulate, mechanically strike off and mechanically consolidate new concrete to a minimum of 98% of the vibrated unit weight and screed to final grade. In irregular areas or along the curb where the finishing screed does not reach, hand tamp with a 6 inch by 6 inch metal plate device to assist in consolidation and bonding of the concrete. When concrete for partial depth patches is placed with the overlay, apply additional vibration or hand tamping in the patch areas to assist in consolidation and bonding of the concrete.

The Engineer will use an approved nuclear density measuring device to monitor in-place density. Hand floating operations may be required to produce a tight, uniform surface. Take every reasonable precaution to secure a smooth riding bridge deck. Correct surface variations exceeding ⅛ inch in 10 feet, unless directed otherwise by the Engineer.

Silica fume concrete is prone to plastic shrinkage because it has no bleed water. To help reduce or eliminate shrinkage cracking, treat with fogging equipment and precure material immediately after strike-off of the surface. If fogging has not been required during placement, start at this point and continue throughout the finishing operation. When the evaporation rate is above 0.2 lbs. per square foot provide continuous fogging. When the evaporation rate is below 0.2 lbs. per square foot, use an intermittent pattern of fogging during the placing and finishing operation to maintain a visually damp surface on the concrete. Close observation of conditions and judgment should be used to maintain a damp surface on the concrete without flooding the surface with excessive water.

When a tight, uniform surface has been achieved, give the surface a suitable texture by transverse grooving with a finned float having a single row of fins. Make the grooving approximately $^3/_{16}$ inch in width on ¾ inch centers, with a groove depth of approximately ⅛ inch. Perform this operation at such time and in such manner that the desired texture shall be achieved while minimizing displacement of the larger aggregate particles. For bridges having drains, the transverse grooving should terminate approximately 2 foot in from the gutter line at the base of the curb. Give the area adjacent to the curbs a light broom finish, longitudinally.

Using an edger having a ¼ inch radius, finish the exposed edges of the end spans of bridges which form a part of the road surface.

d. Curing. Apply Type 1-D liquid membrane forming curing compound immediately behind the tining float. The final cure shall be with wet burlap covered with polyethylene sheeting.

Continue fogging the entire placement to maintain a damp surface until the wet burlap can be applied.

Place the wet burlap as soon as possible without damaging the surface, and keep wet during the 7 day cure period, using soaker hoses or occasional spraying.

If the concrete surface temperature is above 90°F, and air temperatures are predicted to remain above 60°F, do not use polyethylene sheeting in direct sunshine during the day for the first 24 hours of the 7 day curing period. White polyethylene sheeting may be used at night to maintain the required damp condition of the burlap. When polyethylene sheeting is used over the burlap at night during the first 24 hours and the concrete surface temperature is above 90°F, place the polyethylene sheeting a maximum of 1 hour before sunset, and remove the polyethylene sheeting within 1 hour after sunrise. After the first 24 hours, the polyethylene sheeting may be left in place continuously for the remainder of the curing period provided the burlap is kept damp.

At air temperatures below 70°F, black or clear polyethylene sheeting may be used. However, the concrete temperature must not be allowed to exceed 90°F. If the concrete temperature exceeds 90°F, remove the polyethylene sheeting, or replace with white sheeting.

Perform cold weather curing as outlined in **subsection 710.3e.(4)**.

Adhere to **TABLE 710-2** for allowable concrete loads.

e. Weather Limitations. See **subsection 401.8.** Also, discontinue concreting operations when a descending air temperature in the shade and away from artificial heat falls below 45°F except with written approval from the Engineer. Do not start or resume operations until an ascending air temperature reaches 40°F, or if night time temperatures are expected to fall below 35°F.

f. Limitations of Operations. Provide a technical representative of the silica fume manufacturer on the job site during the initial placement of the concrete at no additional cost to KDOT. The representative is to provide technical expertise to the Contractor, concrete producer and the Engineer regarding batching, transport, placement and curing of silica fume concrete. This requirement may be waived for experienced contractors. Submit to the Engineer a request along with a list of silica fume concrete overlay projects completed.

A minimum of 1 day prior to the placement, make a trial placement to gain experience with all aspects of this construction. This requirement may be waived by the Engineer if the Contractor and concrete producer can show significant similar experience with silica fume concrete. Submit to the Engineer a request along with a list of silica fume concrete overlay projects completed by the Contractor and the concrete producer.

When a new deck is involved, do not commence work on the wearing surface until the lower course meets the time requirements of **SECTION 710**, unless specified otherwise.

Do not place concrete adjacent to a surface course, less than 36 hours old. This restriction does not apply to a continuation of placement in a lane or strip beyond a transverse joint in the same lane or strip.

In areas where there is no traffic, preparation of the area may be started in a lane or strip adjacent to newly placed surface the day following its placement. If this work is started before the end of the 7 day curing period, restrict the work as follows:

- Sawing or other operations may interfere with the curing process in the immediate work area for the minimum practical time only;
- Resume the curing promptly upon completion of the work;
- Keep the exposed areas damp until such time as curing media is replaced; and
- Do not use power driven tools heavier than a 15 pound chipping hammer.

g. Construction Joints. Make construction joints (either longitudinal or transverse) by placing and finishing the silica fume concrete approximately 6 inches beyond the desired location of the construction joint. After the silica fume overlay is cured, make a vertical saw cut at the location of the construction joint and chip away the excess silica fume overlay.

h. Sealing Vertical Faces of the Silica Fume Overlay. Seal all construction joints and vertical faces (such as the edge at the curb line) of the silica fume overlay. Sand or shot blast the construction joints and vertical faces, and apply a concrete masonry coating to the cleaned vertical surfaces according to **SECTION 726**.

i. Correction of Unbonded Areas. If during construction of the project, newly overlain areas are discovered to be unbonded by tapping or chaining, outline the concrete from such areas by sawing, remove it with small air tools (15 pound maximum) and replace it at no additional compensation.

717.4 METHOD OF MEASUREMENT AND BASIS OF PAYMENT

The Engineer will measure silica fume overlay by the square yard.

The Engineer will measure material for silica fume overlay by the cubic yard according to the following:

(1) When approved by the District Engineer on repair of existing bridges, this pay item will be used to compensate the Contractor for the additional overlay material that will be required to fill the areas greater than the thickness of overlay shown in the Contract Documents. The Contractor is responsible for maintaining adequate quality control of the demolition process to minimize deviations from the plan grades.

(2) The Engineer will keep a running account of the volume of overlay material that is produced and delivered to the deck. When approved, the Contractor will be paid, at the set price per cubic yard, for all overlay material in excess of 110% of the theoretical volume to cover the deck area with the thickness of overlay shown in the Contract Documents.

Payment for "Silica Fume Overlay" at the contract unit price and "Material for Silica Fume Overlay" at the contract set unit price (when approved by the District Engineer), will be full compensation for the specified work.

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, EDITION 2007

Delete SECTION 401 and replace with the following:

SECTION 401

CONCRETE

401.1 DESCRIPTION

Provide the grades of concrete specified in the Contract Documents.

401.2 MATERIALS

Provide materials that comply with the applicable requirements.

Coarse, Fine and Mixed Aggregate	**DIVISION 1100**
Admixtures, Plasticizers, and Silica Fume	**DIVISION 1400**
Cement, Fly Ash, and Ground Granulated Furnace Slag	**DIVISION 2000**
Water	**DIVISION 2400**

401.3 CONCRETE MIX DESIGN

a. General. Design the concrete mixes specified in the Contract Documents.

Provide aggregate gradations that comply with **SECTION 1102** and Contract Documents.

If desired, contact the DME for available information to help determine approximate proportions to produce concrete having the required characteristics on the project.

Take full responsibility for the actual proportions of the concrete mix, even if the Engineer assists in the design of the concrete mix.

Submit all concrete mix designs to the Engineer for review and approval. Submit completed volumetric mix designs on KDOT Form No. 694 (or other forms approved by the DME).

Do not place any concrete on the project until the Engineer approves the concrete mix designs. Once the Engineer approves the concrete mix design, do not make changes without the Engineer's approval.

Submit test data from KT-73, KT-79 (Appendix B) or AASHTO T-277 for all Silica Fume Modified Concrete and any project with over 250 cubic yards of concrete. Provide the test data for each mix, tested at the highest water-cement ratio. The mix design and test data must be submitted to KDOT at least 60 days prior to placement of concrete on the project. Two options are available for mix design procedures. Use the procedures outlined in **subsection 401.3b.** or Appendix A to design concrete mixes.

b. Concrete Mix Design Based On Previous Data. Provide concrete mix designs based on previous 28-day compressive strength test data from similar concrete mixtures. Similar mixtures are within 1000 psi of the specified 28-day compressive strength, and are produced with the same type and sources of cementitious materials, admixtures and aggregates. Consider sand sources the same, provided they are not more than 25 miles apart on the same river and no tributaries enter the river between the 2 points. Consider crushed locations similar if they are mined in one continuous operation, and there is no significant change in geology. Mixes that have changes of more than 10% in proportions of cementitious materials, aggregates or water content are not considered similar. Air entrained mixes are not considered similar to non-air entrained mixes. Test data should represent at least 30 separate batches of the mix. One set of data is the average of at least 2 cylinders from the batch. The data shall represent a minimum of 45 days of production within the past 12 months. Do not include data over 1 year old. When fewer than 30 data sets are available, the standard deviation of the data must be corrected to compensate for the fewer data points.

Provide a concrete mix design that will permit no more than 5% of the 28-day compressive strength tests to fall below the specified 28-day compressive strength (*f'c*) based on equation A, and no more than 1% of the 28-day compressive strength tests to fall below the specified 28-day compressive strength (*f'c*) by more than 500 psi based on equation B.

Equation A: $f'cr = f'c + 1.62 \cdot k \cdot s$

Equation B: $f'cr = (f'c - 500) + 2.24 \cdot k \cdot s$

Where: $f'cr$ = average 28-day compressive strength required to meet the above criteria.
$f'c$ = specified 28-day compressive strength
s = standard deviation of test data
k = constant based on number of data points
n = number of data points
$k = 1.3 - n / 100$, where $15 < n < 30$
$k = 1$, where $n > 30$

Provide a concrete mix design that has an average compressive strength that is equal to the larger of Equation A or Equation B. Submit all supporting test data with the mix design.

<u>All other concrete mix designs.</u>

For concrete mixes that have fewer than 15 data points, or if no statistical data is available, use Equations A and B to calculate *f'cr* using the following values.

s = 20% of the specified 28-day compressive strength ($f'c$)
$k = 1$

Provide 28-day compressive strength test data at 3 different water–cementitious ratios showing compliance with required *f'cr*. Each set of test data shall be the average of a minimum of 3 cylinders. These mixes shall utilize materials that will be used on the project.

c. Air-Entrained Concrete for Pavement. Design air-entrained concrete for pavement according to **TABLE 401-1**.

TABLE 401-1: AIR-ENTRAINED CONCRETE FOR PAVEMENT

Type of Agg (SEC 1100)	**lb. of Cementitious per yd^3 of Concrete, minimum^1**	**lb. of Water per lb. of Cementitious, maximum^2**	**Percent of Air by Volume^3**	**28-Day Comp Strength psi minimum**	**Volume of Permeable Voids^{4,5}, maximum**	**Surface Resistivity^{4,5}, minimum**	**Rapid Chloride Permeability^{4,5}, maximum**
Coarse and Fine	564	0.47	**See subsection 401.3h.**	4000	12.00%	9.0 kΩ-cm	3000 Coulombs
MA-2							
MA-3	517						
MA-4							

[1] The amount of cementitious listed is the designated minimum for concrete pavement. It may be necessary to add additional cementitious or otherwise adjust the mix proportions as permitted by the specifications to provide a mix design that complies with the compressive strength requirement.

[2] Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

[3] The maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

[4] Provide concrete for pavement with either a maximum 28-day Volume of Permeable Voids of 12.0% as per KT-73, a minimum 28-day Surface Resistivity of 9.0 kΩ-cm as per KT-79 (Appendix B), <u>**or**</u> a maximum 56-day Rapid Chloride Permeability of 3000 Coulombs as per AASHTO T-277 when required. Submit accelerated cure procedures for the Engineer's approval.

[5] **Exclude these requirements for concrete patching material used in SECTION 833 when the existing pavement to be patched is more than 10 years old.**

Improvements in concrete strength, workability and durability are possible if the combined aggregate grading is optimized. Procedures found in ACI 302.1 or other mix design techniques are acceptable in optimizing the mix design.

Use either Air-Entrained Concrete for Pavement or Optimized, Air-Entrained Concrete for Pavement. Provide the Engineer written notification of the selection prior to the pre-construction conference.

Submit the concrete mix design, and supply the Engineer with the necessary materials to enable the Engineer to test the mix properties at least 60 days before the anticipated date of using the design on the project and include the following information:

(1) A single point grading for the combined aggregates along with a plus/minus tolerance for each sieve to the Engineer. Use plus/minus tolerances to perform quality control checks and by the Engineer to perform aggregate grading verification testing. The tests may be performed on the combined materials or on individual aggregates, and then theoretically combined to determine compliance.

(2) Laboratory 28-day compressive strength test results on a minimum of 1 set of 3 cylinders produced from the proposed mix design, utilizing the actual materials proposed for use on the project. Design compressive strength should be a minimum of 2 of the Contractor's normal standard deviations for this type of mix above 4000 psi (cylinders) or meet the requirements of **subsection 401.3b**.

(3) Use historical mix production data for the plant used on the project to substantiate the standard deviation selected. If such historical data is not available or is unacceptable to the Engineer, use 5300 psi for design strength.

The Engineer will provide an initial review of the design within 5 business days following submittal. After initial review, the Engineer will perform any testing necessary to verify the design.

To verify the mix design in the field, perform compressive strength tests on cylinders made from samples taken from concrete produced at the project site before or during the first day that concrete pavement is placed on the project. If the compressive strength tests indicate noncompliance with minimum design values, add additional cement to the mix or make other appropriate mix design changes at no additional cost to KDOT.

d. Air-Entrained Concrete for Shoulders. Design air-entrained concrete for shoulders according to **TABLE 401-2.**

TABLE 401-2: AIR-ENTRAINED CONCRETE FOR SHOULDERS

Type of Aggregate (SECTION 1100)	**lb. of Cementitious per yd^3 of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum[1]**	**Percent of Air by Volume[2]**	**Volume of Permeable Voids[3,4], maximum**	**Surface Resistivity[3,4], minimum**	**Rapid Chloride Permeability[3,4], maximum**
Coarse and Fine	520	0.49	**See subsection 401.3h.**	12.00%	9.0 kΩ-cm	3000 Coulombs
MA-2						
MA-3	480					
MA-4						

[1] Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

[2] The maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

[3] Concrete for shoulders using the same aggregates and gradations as the mainline pavement concrete on the same project will be approved without testing for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability.

[4] Exclude these requirements for concrete patching material used in SECTION 833 when the existing pavement to be patched is more than 10 years old.

e. Concrete for Structures. Design concrete for structures as outlined in **subsection 401.3b.** with a maximum water to cementitious ratio of 0.50 and a minimum cementitious content of 480 lbs per cubic yard according **TABLE 401-3a and 401-3b**.

TABLE 401-3a: CONCRETE FOR STRUCTURES		
Specified 28 Day Compressive Strengths, minimum, psi *f'c*		
Grade of Concrete:	**Non Air Entrained Concrete**	**Air Entrained Concrete**
Grade 6.0	6,000	6,000
Grade 5.0	5,000	5,000
Grade 4.5	4,500	4,500
Grade 4.0	4,000	4,000
Grade 3.5	3,500	3,500
Grade 3.0	3,000	3,000
Grade 2.5	2,500	2,500

(1) Provide air entrained concrete for structures with a target air content of 6.5 ± 1.5 percent.

(2) Maximum air content is 10%. Take immediate steps to reduce the air content whenever the air content exceeds 8%.

(3) Determine air content by KT-19 (Rollometer). A regularly calibrated air meter may be used for production with random verification by the rollometer. See KT-19 for special requirements when using the rollometer with high cementitious concretes or mixtures with midrange water reducers or plasticizers.

TABLE 401-3b: PERMEABILITY REQUIREMENTS FOR CONCRETE FOR STRUCTURES				
	Volume of Permeable Voids[1], maximum	**Surface Resistivity[1], minimum**	**Rapid Chloride Permeability[1], maximum**	**ASTM C-1567[2] Accelerated Mortar Bar Expansion**
Low Permeability Concrete (LPC) Portland Cement Concrete Overlay	9.5%	27.0 kΩ-cm	1000 Coulombs	0.10% @ 16 days
Moderate Permeability Concrete (MPC) Full Depth Bridge Deck.	11.0%	13.0 kΩ-cm	2000 Coulombs	0.10% @ 16 days
Standard Permeability Concrete (SPC) Sub Deck	12.0%	9.0 kΩ-cm	3000 Coulombs	0.10% @ 16 days
Standard Permeability Concrete (SPC), All other Structures	12.0%	9.0 kΩ-cm	3000 Coulombs	0.10% @ 16 days

[1] Perform 28-day Volume of Permeable Voids as per KT-73, 28-day Surface Resistivity as per KT-79 (Appendix B), or 56-day Rapid Chloride Permeability as per AASHTO T-277 when required. Submit accelerated cure procedures for the Engineer's approval.

[2] ASTM C-1567 only required if supplementary cementitious materials (SCMs) are utilized in the concrete.

(1) Use Quality Requirements for Structural Aggregates as listed in Special Provision to the Standard Specification 07-11009 (latest revision) Aggregates For Concrete Not Placed on Grade.

(2) Use gradation requirements for aggregates as listed in Special Provision to the Standard Specification 07-11009 Aggregates For Concrete Not Place on Grade.

(3) Use MA-6 optimized gradation for Low Permeability Concrete for Portland Cement Concrete Overlay.

(4) Improvements in concrete strength, workability and durability are possible if the combined aggregate grading is optimized. Procedures found in ACI 302.1 or other mix design techniques are acceptable in optimizing the mix design.

(5) A water-reducing admixture for improving workability may be required. Adjust the designated slump accordingly.

(6) Adjust the yield cement factor (ycf) for higher air within specification limits, as allowed in the Contract Documents.

(7) When used, add silica fume with other cementitious materials during batching procedures. If the silica fume cannot be added to the cementitious materials it must be added loose to the bottom of the drum previous to the dry materials. The drum shall be wet with no standing water and not turning. The Engineer may approve shreddable bags on a performance basis, only when a central batch mixing

process is used. If so, then add the bags to half of the mixing water and mix before adding cementitious materials, aggregate and remainder of water.

(7) When used, mix silica fume modified concrete for a minimum of 100 mixing revolutions.

(8) Delay the commencement of tests from 4 to 4½ minutes after the sample has been taken from a continuous mixer. If a batch type mixer is used, take the tests at the point of placement and begin testing immediately.

f. Portland Cement and Blended Hydraulic Cement. Unless specified otherwise in the Contract Documents, select the type of portland cement or blended hydraulic cement according to **TABLE 401-5**.

TABLE 401-5: PORTLAND CEMENT & BLENDED HYDRAULIC CEMENT

Concrete for:	Type of Cement Allowed
Portland Cement Concrete Overlay, Silica Fume Overlay and Concrete Pavement	Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland-Blast Furnace Slag Cement Type IT(Ax)(By) Ternary Blended Cement Type II Portland Cement
All Structures other than Portland Cement Concrete Overlay, Silica Fume Overlay and Concrete Pavement	Type I Portland Cement Type IP(x) Portland-Pozzolan Cement Type IS(x) Portland-Blast Furnace Slag Cement Type IT(Ax)(By) Ternary Blended Cement Type II Portland Cement
High Early Strength Concrete	Type III Portland Cement Type I, IP(x), IS(x), IT(Ax)(By), or II Cement may be used if strength and time requirements are met.

g. Design Air Content. With the exception of concrete for PCCP, use the middle of the specified air content range for the design of air-entrained concrete.

For PCCP concrete, provide a minimum air content that complies with these 2 criteria:

- a minimum by volume of 5.0% behind the paver, and
- a maximum air void spacing factor of 0.01 inch behind the paver[1].

For a typical PCCP, design the mix at the target air content plus 0.5% air content.

The target air content is the air content that meets both criteria above.

If the air void spacing factor exceeds 0.01 inch, use the following formula as a guide to determine the target air content[1]:

Target % air content at 0.01 inch = % air measured + (measured spacing factor – 0.01)/0.001

Mixes with Laboratory or Field Prequalification spacing factors greater than 0.01 inch will not be approved.

Take immediate steps to reduce the spacing factor whenever the spacing factor exceeds 0.01 inch. Suspend paving operations when the spacing factor exceeds 0.015 inches and remove and replace the represented concrete[1].

Take immediate steps to increase the air content whenever the air content behind the paver falls below 5.0%. Suspend paving operations when 2 consecutive air contents behind the paver fall below 4.0% and remove and replace the represented concrete.

[1] Does not apply to concrete used in Section 833 when existing pavement to be patched is more than 10 years old.

h. Admixtures for Acceleration, Air-Entraining, Plasticizing, Set Retardation and Water Reduction. Verify that the admixtures used are compatible and will work as intended without detrimental effects. Use the dosages recommended by the admixture manufacturers. Incorporate and mix the admixtures into the concrete mixtures according to the manufacturer's recommendations. Determine the quantity of each admixture for the concrete mix design.

Redosing is permitted to accomplish slump control or air content in the field, when approved by the Engineer, time and temperature limits are not exceeded, and at least 30 mixing revolutions remain before redosing. Redose with up to 50% of the original dose.

If another admixture is added to an air-entrained concrete mixture, determine if it is necessary to adjust the air-entraining admixture dosage to maintain the specified air content.

(1) Accelerating Admixture. When specified in the Contract Documents, or in situations that involve contact with reinforcing steel and require early strength development to expedite opening to traffic, a non-chloride accelerator may be approved. The Engineer may approve the use of a Type C or E accelerating admixture. A Grade 2 calcium chloride accelerator may be used when patching an existing pavement more than 10 years old.

Add the calcium chloride by solution (the solution is considered part of the mixing water).

- For a minimum cure of 4 hours at 60°F or above, use 2% (by dry weight of cement) calcium chloride.
- For a minimum cure of 6 hours at 60°F or above, use 1% (by dry weight of cement) calcium chloride.

(2) Air-Entraining Admixture. When specified, use an air-entrainer in the concrete mixture.

(3) Water-Reducers and Set-Retarders. If unfavorable weather or other conditions adversely affect the placing and finishing properties of the concrete mix, the Engineer may allow the use of water-reducers and set-retarders. If the Engineer approves the use of water-reducers and set-retarders, their continued use depends on their performance. Verify that the admixtures will work as intended without detrimental effects. If at any point, a water-reducer is used to produce a slump equal to or greater than 7 ½ inches, comply with **subsection 401.3i.(4)**.

(4) Plasticizer Admixture. A plasticizer is defined as an admixture that produces flowing concrete, without further addition of water, and/or retards the setting of concrete. Flowing concrete is defined as having a slump equal to or greater than 7 ½ inches.

Include a batching sequence in the concrete mix design. Consider the location of the concrete plant in relation to the job site, and identify when and at what location the plasticizer is added to the concrete mixture. Do not add water after the plasticizer is added to the concrete mixture.

Manufacturers of plasticizers may recommend mixing revolutions beyond the limits specified in **subsection 401.8**. If necessary, address the additional mixing revolutions in the concrete mix design. The Engineer may allow up to 60 additional revolutions when plasticizers are designated in the mix design.

Before the concrete mixture with a slump equal to or greater than 7 ½ inches is used on the project, conduct tests on at least 1 full trial batch of the concrete mix design to determine the adequacy of the dosage and the batching sequence of the plasticizer to obtain the desired properties. Determine the air content of the trial batch both before and after the addition of the plasticizer. Monitor the slump, air content, temperature and workability at regular intervals of the time period from when the plasticizer is added until the estimated time of completed placement. At the discretion of the Engineer, if all the properties of the trial batch remain within the specified limits, the trial batch may be used in the project.

The Engineer will allow minor adjustments to the dose rate to compensate for environmental changes during placement without a new concrete mix design or trial batch.

i. Slump. Designate a slump for each concrete mix design that is within the limits in **TABLE 401-6**.

TABLE 401-6: ALLOWABLE CONCRETE SLUMP

Concrete Use	*Maximum Allowable Slump (inches)*
Concrete Pavement	2 ½(1)(2)
Concrete for Structures & Air-Entrained Concrete for Structures	That required for satisfactory placement of the respective parts of the structure.(2)
Bridge Subdecks or Decks without Plasticizing Admixtures	3(2)
Concrete with Plasticizing Admixture for Structures, Bridge Subdecks or Decks, Air-Entrained Concrete with Plasticizing Admixture for Structures, & Concrete with Plasticizing Admixture for Prestressed Beams	7(3)
Concrete with Plasticizers for Drilled Shafts	(4)

(1)If the Engineer approves, slumps in excess of 2 ½ inches are allowed for areas that are hand finished.

(2)If the designated slump is 3 inches or less, the tolerance is ±¾ inch, or limited by the maximum allowable slump for the individual type of construction. If the designated slump is greater than 3 inches (without plasticizing admixture), the tolerance is ±25% of the designated slump.

[3]If the Engineer approves the use of plasticizing admixture in the concrete, the tolerance from the designated slump is ±25% or ¾ inch, whichever is larger, limited by the maximum allowable slump for the individual type of construction. Maintain the required geometry.
[4]The target slump just prior to being pumped into the drilled shaft is 9 inches. If the slump is less than 8 inches, then redose the concrete as permitted in **subsection 401.3i**.

j. Field Blended Cement Concrete. When approved by the Engineer, the concrete mix design may include supplementary cementitious materials (SCM) such as fly ash or ground granulated blast furnace slag (GGBFS) from an approved source as a partial replacement for portland cement or blended hydraulic cement. Obtain the Engineer's approval before substituting SCMs for Type III cement. The approved source of SCM may not be changed during the project.

Supplementary materials may be inter-ground, plant blended or field blended. Supplementary materials can be combined with cement to create binary or ternary concrete mixes. Do not exceed allowable substitution rates noted in **TABLE 401-8**. Substitute 1 pound of SCM for 1 pound of cement.

TABLE 401-8: ALLOWABLE SUBSTITUTION RATE FOR SUPPLEMENTARY CEMENTITIOUS MATERIAL.

Material	Substitution Rate*
Slag Modified	40% Maximum
C Fly Ash Modified	25% Maximum
F Ash Modified	25% Maximum
Silica Fume Modified	5% Max
Total Combined	50%

* Total Substitution Rate includes material in pre-blended cements.

Design field blended cement concrete meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability using the parameters described in **subsection 401.3b**.

Submit complete mix design data including proportions and sources of all mix ingredients, and the results of strength tests representing the mixes proposed for use. The strength data may come from previous KDOT project records or from a laboratory regularly inspected by Cement and Concrete Reference Laboratory (CCRL), and shall equal or exceed the strength requirements for the Grade specified in the Contract Documents. Perform compressive strength tests according to AASHTO T-22.

Provide the results of mortar expansion tests of ASTM C 1567 using the project's mix design concrete materials at their designated percentages. Provide a mix with a maximum expansion of 0.10 % at 16 days after casting.

Provide the results to the Engineer at least 60 days before placement of concrete on the project.

k. High Early Strength Concrete. Design the high early strength concrete mix to comply with strength and time requirements specified in the Contract Documents. Unless otherwise specified, design high early strength concrete for pavement at a minimum of 1 of the Contractor's standard deviations above 2400 psi (cylinders) at 24 hours.

Submit complete mix design data including proportions and sources of all mix ingredients, and the results of time and strength tests representing the mixes proposed for use. The strength and time data may come from previous KDOT project records or from an independent laboratory, and shall equal or exceed the strength and time requirements listed in the Contract Documents.

401.4 MORTAR AND GROUT

a. General. Follow the proportioning requirements in **subsection 401.4b.** and **c.** for mortar and grout unless otherwise specified in the Contract Documents, including altering the proportions when a minimum strength is specified.

b. Mortar. Mortar is defined as a mixture of cementitious materials, fine aggregate and water, which may contain admixtures, and is typically used to minimize erosion between large stones or to bond masonry units.

Proportion mortar for laying stone for stone rip-rap, slope protection, stone ditch lining or pavement patching at 1 part of portland cement and 3 parts of fine aggregate by volume with sufficient water to make a workable and plastic mix.

Proportion mortar for laying brick, concrete blocks or stone masonry at ½ part masonry cement, ½ part portland cement and 3 parts fine aggregate, either commercially produced masonry sand or FA-M, by volume with sufficient water to make a workable and plastic mix.

Do not use air-entraining agents in mortar for masonry work.

The Engineer may visually accept the sand used for mortar. The Engineer may visually accept any recognized brand of portland cement or masonry cement that is free of lumps.

c. Grout. Grout is defined as a mixture of cementitious materials with or without aggregate or admixtures to which sufficient water is added to produce a pouring or pumping consistency without segregation of the constituent materials and meeting the applicable specifications.

401.5 COMMERCIAL GRADE CONCRETE

If the Contract Documents allow the use of commercial grade concrete for designated items, then use a commercial grade mixture from a ready-mix plant approved by the Engineer.

The Engineer must approve the commercial grade concrete mixture. Approval of the commercial grade mixture is based on these conditions:

- All materials are those normally used for the production and sale of concrete in the vicinity of the project.
- The mixture produced is that normally used for the production and salë of concrete in the vicinity of the project.
- The mixture produced contains a minimum cementitious content of 6 sacks, 564 lbs, of cementitious per cubic yard of concrete.
- The water-cementitious ratio is as designated by the Engineer. The maximum water-cementitious ratio permitted may not exceed 0.55 pounds of water per pound of cementitious including free water in the aggregate.
- Type I, II, III, IP, IS, or IT cement may be used unless otherwise designated. Fly ash or GGBFS may be substituted for the required minimum cement content as specified in **subsection 401.3**. No additives other than air entraining agent will be allowed. The Contractor will not be required to furnish the results of strength tests when submitting mix design data to the Engineer.
- In lieu of the above, approved mix designs (including optimized) for all other grades of concrete, Grade 3.0 or above, are allowable for use as commercial grade concrete, at no additional cost to KDOT.

Exercise good engineering judgement in determining what equipment is used in proportioning, mixing, transporting, placing, consolidating and finishing the concrete.

Construct the items with the best current industry practices and techniques.

Before unloading at the site, provide a delivery ticket for each load of concrete containing the following information:

- Name and location of the plant.
- Time of batching concrete.
- Mix proportions of concrete (or a mix designation approved by the Engineer).
- Number of cubic yards of concrete batched.

Cure the various items placed, as shown in **DIVISION 700**.

The Engineer may test commercial grade concrete by molding sets of 3 cylinders. This is for informational purposes only. No slump or unit weight tests are required.

401.6 CERTIFIED CONCRETE

If KDOT inspection forces are not available on a temporary basis, the Engineer may authorize the use of concrete from approved concrete plants. Approval for this operation is based on certification of the plant and plant personnel, according to KDOT standards. KDOT's approval may be withdrawn any time that certification procedures are not followed.

The Engineer will not authorize the use of certified concrete for major structures such as bridges, RCB box bridges, RCB culverts, permanent main line and ramp pavement or other structurally, critical items.

Each load of certified concrete must be accompanied by a ticket listing mix proportions, time of batching and setting on revolution counter, total mixing revolutions and must be signed by certified plant personnel.

401.7 REQUIREMENTS FOR COMBINED MATERIALS

a. Measurements for Proportioning Materials.

(1) Cement. Measure cement as packed by the manufacturer. A sack of cement is considered as 0.04 cubic yards weighing 94 pounds net. Measure bulk cement by weight. In either case, the measurement must be accurate to within 0.5% throughout the range of use.

(2) Fly Ash. Fly ash proportioning and batching equipment is subject to the same controls as required for cement. Provide positive cut off with no leakage from the fly ash cut off valve. Fly ash may be weighed accumulatively with the cement or separately. If weighed accumulatively, weigh the cement first.

(3) Water. Measure the mixing water by weight or by volume. In either case, the measurement must be accurate to within 1% throughout the range of use.

(4) Aggregates. Measure the aggregates by weight. The measurement must be accurate to within 0.5% throughout the range of use.

(5) Admixtures. Measure liquid admixtures by weight or volume. If liquid admixtures are used in small quantities in proportion to the cement as in the case of air-entraining agents, use readily adjustable mechanical dispensing equipment capable of being set to deliver the required quantity and to cut off the flow automatically when this quantity is discharged. The measurement must be accurate to within 3% of the quantity required.

b. Testing of Aggregates.

(1) Production of On Grade Concrete Aggregate (OGCA). If OGCA is required, notify the Engineer in writing at least 2 weeks in advance of producing the aggregate. Include the source of the aggregate and the date production will begin. Failure to notify the Engineer, as required, may result in rejection of the aggregate for use as OGCA. Maintain separate stockpiles for OGCA at the quarry and at the batch site and identify them accordingly.

(2) Testing Aggregates at the Batch Site. Provide the Engineer with reasonable facilities at the batch site for obtaining samples of the aggregates. Provide adequate and safe laboratory facilities at the batch site allowing the Engineer to test the aggregates for compliance with the specified requirements.

KDOT will sample and test aggregates from each source to determine their compliance with specifications. Do not batch the concrete mixture until the Engineer has determined that the aggregates comply with the specifications. KDOT will conduct sampling at the batching site, and test samples according to the Sampling and Testing Frequency Chart in Part V. For QC/QA Contracts, establish testing intervals within the specified minimum frequency.

After initial testing is complete and the Engineer has determined that the aggregate process control is satisfactory, use the aggregates concurrently with sampling and testing as long as tests indicate compliance with specifications. When batching, sample the aggregates as near the point of batching as feasible. Sample from the stream as the storage bins or weigh hoppers are loaded. If samples can not be taken from the stream, take them from approved stockpiles, or use a template and sample from the conveyor belt. If test results indicate an aggregate does not comply with specifications, cease concrete production using that aggregate. Unless a tested and approved stockpile for that aggregate is available at the batch plant, do not use any additional aggregate from that source and specified grading until subsequent testing of that aggregate indicate compliance with specifications. When tests are completed and the Engineer is satisfied that process control is satisfactory, production of concrete using aggregates tested concurrently with production may resume.

c. Handling of Materials.

(1) Approved stockpiles are permitted only at the batch plant and only for small concrete placements or for maintaining concrete production. Mark the approved stockpile with an "Approved Materials" sign. Provide a suitable stockpile area at the batch plant so that aggregates are stored without detrimental segregation or contamination. At the plant, limit stockpiles of tested and approved coarse aggregate and fine aggregate to 250 tons each, unless approved for more by the Engineer. If mixed aggregate is used, limit the approved stockpile to 500 tons, the size of each being proportional to the amount of each aggregate to be used in the mix.

Load aggregates into the mixer such that no material foreign to the concrete or material capable of changing the desired proportions is included. When 2 or more sizes or types of coarse or fine aggregates are used on the same project, only 1 size or type of each aggregate may be used for any one continuous concrete placement.

(2) Segregation. Do not use segregated aggregates. Previously segregated materials may be thoroughly re-mixed and used when representative samples taken anywhere in the stockpile indicated a uniform gradation exists.

(3) Cement, Fly Ash and GGBFS. Protect cement, fly ash and GGBFS in storage or stockpiled on the site from any damage by climatic conditions which would change the characteristics or usability of the material.

(4) Moisture. Provide aggregate with a moisture content of ± 0.5% from the average of that day. If the moisture content in the aggregate varies by more than the above tolerance, take whatever corrective measures are necessary to bring the moisture to a constant and uniform consistency before placing concrete. This may be accomplished by handling or manipulating the stockpiles to reduce the moisture content, or by adding moisture to the stockpiles in a manner producing uniform moisture content through all portions of the stockpile.

For plants equipped with an approved accurate moisture-determining device capable of determining the free moisture in the aggregates, and provisions made for batch to batch correction of the amount of water and the weight of aggregates added, the requirements relative to manipulating the stockpiles for moisture control will be waived. Any procedure used will not relieve the producer of the responsibility for delivering concrete of uniform slump within the limits specified.

(5) Separation of Materials in Tested and Approved Stockpiles. Only use KDOT Approved Materials. Provide separate means for storing materials approved by KDOT. If the producer elects to use KDOT Approved Materials for non-KDOT work, during the progress of a project requiring KDOT Approved Materials, inform the Engineer and agree to pay all costs for additional materials testing.

Clean all conveyors, bins and hoppers of any unapproved materials before beginning the manufacture of concrete for KDOT work.

401.8 MIXING, DELIVERY AND PLACEMENT LIMITATIONS

a. Concrete Batching, Mixing and Delivery. Batch and mix the concrete in a central mix plant, in a truck mixer or in a drum mixer at the work site. Provide plant capacity and delivery capacity sufficient to maintain continuous delivery at the rate required. The delivery rate of concrete during concreting operations must provide for the proper handling, placing and finishing of the concrete.

Seek the Engineer's approval of the concrete plant/batch site by the Engineer before any concrete is produced for the project. The Engineer will inspect the equipment, the method of storing and handling of materials, the production procedures and the transportation and rate of delivery of concrete from the plant to the point of use. The Engineer will grant approval of the concrete plant/batch site based on compliance with the specified requirements. The Engineer may, at any time, rescind permission to use concrete from a previously approved concrete plant/batch site upon failure to comply with the specified requirements.

Clean the mixing drum before it is charged with the concrete mixture. Charge the batch into the mixing drum such that a portion of the water is in the drum before the aggregates and cementitious. Uniformly flow materials into the drum throughout the batching operation. All mixing water must be in the drum by the end of the first 15 seconds of the mixing cycle. Keep the throat of the drum free of accumulations restricting the flow of materials into the drum.

Do not exceed the rated capacity (cubic yards shown on the manufacturer's plate on the mixer) of the mixer when batching the concrete. The Engineer may allow an overload of up to 10% above the rated capacity for central mix plants and drum mixers at the work site, provided the concrete test data for strength, segregation and uniform consistency are satisfactory, and no concrete is spilled during the mixing cycle.

Operate the mixing drum at the speed specified by the mixer's manufacturer (shown on the manufacturer's plate on the mixer).

Mixing time is measured from the time all materials, except water, are in the drum. If it is necessary to increase the mixing time to obtain the specified percent of air in air-entrained concrete, the Engineer will determine the mixing time.

If the concrete is mixed in a central mix plant or a drum mixer at the work site, mix the batch between 1 to 5 minutes at mixing speed. Do not exceed the maximum total 60 mixing revolutions. Mixing time begins after all materials, except water, are in the drum, and ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. Mix time may be reduced for plants utilizing high performance mixing drums provided thoroughly mixed and uniform concrete is being produced with the proposed mix time. Performance of the plant must conform with Table A1.1 of ASTM C 94, Standard Specification for Ready Mixed Concrete. Five of the 6 tests listed in Table A1.1 must be within the limits of the specification to indicate that uniform concrete is being produced.

If the concrete is mixed in a truck mixer, mix the batch between 70 and 100 revolutions of the drum or blades at mixing speed. After the mixing is completed, set the truck mixer drum at agitating speed. Unless the mixing unit is equipped with an accurate device indicating and controlling the number of revolutions at mixing speed, perform the mixing at the batch plant and operate the mixing unit at agitating speed while travelling from the plant to the work site. Do not exceed 300 total revolutions (mixing and agitating).

If a truck mixer or truck agitator is used to transport concrete that was completely mixed in a stationary central mixer, agitate the concrete while transporting at the agitating speed specified by the manufacturer of the equipment (shown on the manufacturer's plate on the equipment). Do not exceed 200 total revolutions (additional re-mixing and agitating).

Provide a batch slip including batch weights of every constituent of the concrete and time for each batch of concrete delivered at the work site, issued at the batching plant that bears the time of charging of the mixer drum with cementitious and aggregates. Include quantities, type, product name and manufacturer of all admixtures on the batch ticket.

On paving projects and other high volume work, the Engineer will determine the haul time, and whether tickets will be required for every load. Thereafter, random checks of the loads will be made.

When non-agitating equipment is used for transportation of concrete, provide approved covers for protection against the weather when required by the Engineer.

Place non-agitated concrete within 30 minutes of adding the cement to the water.

Place concrete within the time and temperature conditions shown in **TABLE 401-9**.

TABLE 401-9: AMBIENT AIR TEMPERATURE AND AGITATED CONCRETE PLACEMENT TIME

T = Ambient Air Temperature at Time of Batching (°F)	Specimen Age Time limit agitated concrete must be placed within, after the addition of cement to water (hours)	Admixtures
T < 75	1 ½	None
75 ≤ T	1	None
75 ≤ T < 90	1 ½	Set Retarder

In all cases, if the concrete temperature at time of placement is 90°F or above, or under conditions contributing to quick stiffening of the concrete, place the concrete within 45 minutes of adding the cement to the water. Do not use concrete that has developed its initial set. Regardless of the speed of delivery and placement, the Engineer will suspend the concreting operations until corrective measures are taken, if there is evidence that the concrete can not be adequately consolidated.

Weather conditions and the use of admixtures can effect the set times for the concrete. Do not use the time limits and total revolutions as the sole criterion for rejection of concrete. Exceed the time limits and total revolutions only after demonstrating that the properties of the concrete can be improved. Evaluation of the consistency and workability should be taken into consideration. However, concrete that cannot be adequately consolidated should be rejected.

Adding water to concrete after the initial mixing is prohibited, with this exception:
If the concrete is delivered to the work site in a truck mixer, the Engineer will allow water (up to 2 gallons per cubic yard) be withheld from the mixture at the batch site, and if needed, added at the work site to adjust the slump to the specified requirements. Determine the need for additional water as soon as the load arrives at the construction site. Use a calibrated water-measuring device to add the water, and add the water to the entire load. Do not add more water than was withheld at the batch site. After the additional water is added, turn the drum or blades an additional 20 to 30 revolutions at mixing speed. The Engineer will supervise the adding of water to the load, and will allow this procedure only once per load.

b. Placement Limitations.

(1) Placing Concrete at Night. Do not mix, place or finish concrete without sufficient natural light, unless an adequate, artificial lighting system approved by the Engineer is provided.

(2) Placing Concrete in Cold Weather. Unless authorized by the Engineer, discontinue mixing and concreting operations when the descending ambient air temperature reaches 40°F. Do not begin concreting operations until an ascending ambient air temperature reaches 35°F and is expected to exceed 40°F.

If the Engineer permits placing concrete during cold weather, aggregates may be heated by either steam or dry heat system before placing them in the mixer. Use an apparatus that heats the mass uniformly and is so arranged as to preclude the possible occurrence of overheated areas which might injure the materials. Do not heat aggregates directly by gas or oil flame or on sheet metal over fire. Aggregates that are heated in bins, by steam-coil or water-coil heating, or by other methods not detrimental to the aggregates may be used. The use of live steam on or through binned aggregates is prohibited. Unless otherwise authorized, maintain the temperature of the mixed concrete between 50 to 90°F at the time of placing. Do not, under any circumstances, continue concrete operations if the ambient air temperature is less than 20°F.

If the ambient air temperature is 35°F or less at the time the concrete is placed, the Engineer may require that the water and the aggregates be heated to between 70 and 150°F.

Do not place concrete on frozen subgrade or use frozen aggregates in the concrete.

As a general rule, do not use fly ash, GGBFS or blended cement between the dates of October 1 and April 1. However, if weather conditions are unseasonably warm, the Engineer may waive this rule on a day by day basis. The Engineer will consider the nighttime temperatures, the extended weather forecast and the performance and setting of the mix when deciding whether to waive the restrictions.

401.9 INSPECTION AND TESTING

Unless otherwise designated in the Contract Documents or by the Engineer, obtain samples of fresh concrete for the determination of slump, weight per cubic yard and percent of air from the final point of placement.

The Engineer will cast, store and test strength test specimens in sets of 3.

KDOT will conduct the sampling and test the samples according to **DIVISION 2500** and the Sampling and Testing Frequency Chart in Part V. For QC/QA Contracts, establish testing intervals within the specified minimum frequency.

The Engineer will reject concrete that does not comply with specified requirements.

The Engineer will permit occasional deviations below the specified cementitious content, if it is due to the air content of the concrete exceeding the designated air content, but only up to the maximum tolerance in the air content.

The Contractor has the option to control air content for PCCP by either the Non QC/QA Approach or the QC/QA Approach (see **subsection 401.10** or **401.11**, the Contractor's Quality Control Plan for PCCP shall designate which approach will be used). Continuous operation below the specified cementitious content for any reason is prohibited.

As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions if conditions warrant such changes to produce a satisfactory mix. Any such changes may be made within the limits of the specifications at no additional compensation to the Contractor.

401.10 AIR-ENTRAINED CONCRETE PAVEMENT (NON-QC/QA APPROACH)

a. Air Content for PCCP. Provide an air content that complies with **subsection 401.3 h**.

Using fresh concrete, the Engineer will determine the air void spacing factor using the AVA according to the manufacturer's requirements. Prequalify mixtures by either the laboratory option or the field option. Contact the Engineer to arrange testing by the AVA.

b. Laboratory Prequalification. Prepare a trial mix using a drum-type mixer according to AASHTO T 126 using all of the materials in the proportions, except the air entraining agent, contemplated for use in the field. Laboratory mixes require more air entraining agent than is needed in the field. Consolidate a sample in the unit weight bucket by vibration according to KT-20. Obtain 3 samples from the unit weight bucket for testing by the AVA. Valid results must have a minimum of 2 spacing factor readings within a range of 0.0025 inch. Test the third sample if the first two do not meet this criteria. Determine the air content of the trial mix by KT-19 (Roll-a-meter) or KT-18 (pressure meter) calibrated to yield the same result. Calculate a target percent air content at a maximum air void spacing factor of 0.01 inch using the equation in **subsection 401.3h.**, when applicable.

c. Field Prequalification. Previous data on air content and air void spacing factors may be submitted as a basis of prequalification for a mixture if the same materials, proportions, equipment and procedures are used. The only exception allowed is a change in coarse aggregate sources if the gradation is similar. The new aggregate source is required to meet the same qualifications as the previous aggregate source. Alternately, produce a trial batch at a minimum air temperature of 60°F using the batch plant and project materials. Test for air content by the procedure specified under laboratory prequalification. Correlate this air content to the average of at least 2 valid AVA test results. Valid AVA results have a maximum range of 0.0025 inch.

When necessary, calculate a target percent air content at a maximum air void spacing factor of 0.01 inch, using the equation in **subsection 401.3h**.

d. Field Verification. Coordinate with the Engineer so production samples may be obtained behind the paver to establish the target air content on the first paving day. Produce concrete using the same materials and proportions that were used in the prequalification mixture. Adjustments may be approved in the dosage of air entraining agent and a 5% adjustment may be approved in the water-cementitious ratio. Samples will be taken both in the path of a vibrator and the gap between vibrators. Perform the test for air content at the delivery site of the concrete KT-19 (Roll-a-meter) or KT-18 (pressure meter), calibrated to yield the same result. Make adjustments in the proportions, types of material or the operation to establish a satisfactory, target air content.

e. Control of the Air Content During Paving Operations. Maintain an air content behind the paver as determined by KT-19 or KT-18, which meets **subsection 401.3h**. Maintain all production parameters established during field verification. The dosage of air-entraining agent may be varied to control the air content. Five percent adjustments will be permitted to the cementitious content and the water-cementitious ratio. With AVA testing, 5% adjustments will be permitted to the aggregate proportions, as well as any adjustment to the water reducer. Comply with all specifications regarding production of fresh concrete. For all mainline paving, test the concrete at the beginning of the day's operation and approximately every 2 hours thereafter for air content. For all other slipformed pavement, test for air content at the beginning of a day's operation and approximately every 4 hours thereafter. Test hand placements for air content at least once daily.

Determine the air loss due to paving operations once in the AM and once in the PM. Determine the difference between the air content from concrete sampled before the paver, and concrete sampled behind the paver. QC/QA samples may be obtained in front of the paver and then corrected subtracting the difference determined during that ½ days production. Loss of air due to paving operations may adversely affect the spacing factor.

Failure to maintain the minimum required air content will result in suspension of operation. Take immediate steps to increase the air content above the minimum values stated in **subsection 401.3h**.

Other similar designs using higher cementitious contents and the same admixture types and dosage (with the same or lower water-cementitious ratio) may be used in limited areas such as crossovers, etc. Unauthorized changes in any aspect of production are cause for rejection of the pavement.

Random checks of the air void spacing factor of the concrete in the path and gap of the vibrators will be conducted by the Engineer to verify a maximum spacing factor of 0.01 inch at the measured air content.

APPENDIX A

a. Concrete for Structures. Design field blended cement concrete meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability using the parameters described in **subsection 401.3b**.

TABLE 401-A1: CONCRETE FOR STRUCTURES		
Grade of Concrete: Type of Aggregate (DIVISION 1100)	**lb. of Cementitious per yd^3 of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum[1]**
Grade 5.0:		
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.36
Coarse and Fine Aggregate	602	0.36
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.36
Grade 4.5:		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.42
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.42
Coarse and Fine Aggregate	602	0.42
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.42
Grade 4.0[2]:		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.46
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.46
Coarse and Fine Aggregate	602	0.46
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.46
Grade 3.0 and Grade 3.5:		
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	639	0.48
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	602	0.48
Coarse and Fine Aggregate	564	0.48
MA-2 with 45% or more (by weight) on the No. 4 sieve	564	0.48
Grade 2.5:		
All Aggregates	526	0.55

[1] Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

[2] Take measures to control bleeding on Grade 4.0 concrete for drilled shafts through the use of a lower w/c ratio, the addition of air, or any other proven method to control bleeding.

b. Air-Entrained Concrete for Structures. Design air-entrained concrete for structures meeting the applicable requirements for Volume of Permeable Voids, Surface Resistivity, or Rapid Chloride Permeability, according to **TABLE 401-A2.**

TABLE 401-A2: AIR-ENTRAINED CONCRETE FOR STRUCTURES

Grade of Concrete Type of Aggregate (DIVISION 1100)	**lb. of Cementitious per yd^3 of Concrete, minimum**	**lb. of Water per lb. of Cementitious, maximum [5]**	**Percent of Air by Volume [6]**
Grade 6.0(AE)(SA) [2]:			
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	752	0.35	6.5±1.5
Coarse and Fine Aggregate	752	0.35	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	700	0.35	6.5±1.5
Grade 5.0(AE), Grade 5.0(AE)(SW) [1], Grade 5.0(AE)(SA) [2], Grade 5.0(AE)(AI) [3] and Grade 5.0(AE)(PB) [4] :			
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.35	6.5±1.5
Coarse and Fine Aggregate	602	0.35	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.35	6.5±1.5
Grade 4.5(AE), Grade 4.5(AE)(SW) [1], Grade 4.5(AE)(SA) [2], and Grade 4.5(AE)(AI) [3]:			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.40	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.40	6.5±1.5
Coarse and Fine Aggregate	602	0.40	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.40	6.5±1.5
Grade 4.0(AE), Grade 4.0(AE)(SW) [1], Grade 4.0(AE)(SA) [2], and Grade 4.0(AE)(AI) [3]:			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	696	0.44	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	639	0.44	6.5±1.5
Coarse and Fine Aggregate	602	0.44	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	602	0.44	6.5±1.5
Grade 3.0(AE) and Grade 3.5(AE):			
Mixed aggregate with less than 30% (by weight) on the No. 4 sieve	639	0.46	6.5±1.5
Mixed aggregate with 30% or more (by weight) on the No. 4 sieve	602	0.46	6.5±1.5
Coarse and Fine Aggregate	564	0.46	6.5±1.5
MA-2 with 45% or more (by weight) on the No. 4 sieve	564	0.46	6.5±1.5
Grade 2.5(AE):			
All Aggregates	526	0.53	6.5±1.5

[1] Grade xx (AE)(SW) - Structural concrete with select coarse aggregate for wear.

[2] Grade xx (AE)(SA) - Structural concrete with select coarse aggregate for wear and absorption.

[3] Grade xx (AE)(AI) - Structural concrete with select coarse aggregate for wear and acid insolubility.

[4] Grade xx (AE)(PB) - Structural concrete with select aggregate for use in prestressed concrete beams.

[5] Maximum limit of lb. of water per lb. of cementitious includes free water in aggregates, but excludes water of absorption of the aggregates.

[6] The maximum air content is 10%. Take immediate steps to get the air down whenever the air content exceeds 8%.

c. Silica Fume Modified Concrete. When silica fume is specified in the Contract Documents, meet the mix design and production requirements in **TABLE 401-A3**.

TABLE 401-A3: SILICA FUME CONCRETE CRITERIA	
lbs. of Cement per cu. yd. maximum	595
lbs. of Silica Fume per cu. yd., maximum	30
lbs. of water per lbs. of (Cement + Silica Fume), Max	0.40
Percent of Air by Volume	6.5±1.5[1]
Maximum 56 day Rapid Chloride Permeability C-1202[2]	1000 coulombs
or Maximum 28 day Permeable Voids KT-73 [2]	9.50%
or Minimum 28 day Surface Resistivity KT-79[2]	27.0 kΩ-cm

[1] As Determined by KT-19 (Rollometer). A regularly calibrated air meter may be used for production with random verification by the rollometer. See KT-19 for special requirements when using the rollometer with high cement concretes or mixtures with midrange water reducers or plasticizers.

[2] Provide Silica Fume Modified Concrete with either a maximum 28-day Volume of Permeable Voids of 9.5% as per KT-73, a minimum 28-day Surface Resistivity of 27.0 kΩ-cm as per KT-79 (Appendix B), **or** a maximum 56-day Rapid Chloride Permeability of 1000 Coulombs as per AASHTO T-277. Submit accelerated cure procedures for the Engineer's approval.

APPENDIX B

5.9.79 SURFACE RESISTIVITY INDICATION OF CONCRETE'S ABILITY TO RESIST CHLORIDE ION PENETRATION (Kansas Test Method KT-79)

1. SCOPE

This test method covers the determination of the electrical resistivity of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is based on procedures found in AASHTO TP95-11.

2. REFERENCED DOCUMENTS

2.1. KDOT Construction Manual, Part V, Section, 5.9; Sampling and Test Methods Forward

2.2. KT-22; Making and Curing Compression and Flexural Test Specimens in the Field

2.3. KT-49; Method for Obtaining and Testing Drilled Cores From PCCP and Precast Girders

2.4. KT-73; Density, Absorption and Voids in Hardened Concrete

2.5. KT-76; Method for Testing the Compressive Strength of Molded Cylindrical Concrete Specimens

2.6. AASHTO TP95-11; Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration

3. APPARATUS

3.1. Surface Resistivity meter with a Wenner linear four-probe array. The meter should have a range of 0 to 100 kΩ-cm, with a resolution of 0.1 kΩ-cm and an accuracy of +/- 2% of reading. The Wenner probe array spacing should be set at 1.5 inches (38.1 mm). The meter should be a single, self contained handheld unit.

NOTE: The Proceq Resipod meets these specifications.

4. TEST SPECIMEN

4.1. Prepare 3 samples per mix design. The samples shall be 4" x 8" (100mm X 200mm) cylinders cast at time of mixing or 4" (100mm) cores taken from in-situ concrete. Cylinders shall be molded in accordance with **KT -22** of this manual and cores shall be obtained in accordance with **KT-49** of this manual except as noted in section **5. CURING AND CONDITIONING.**

5. CURING AND CONDITIONING

5.1. Initial curing of cast samples: Cast samples must undergo initial curing procedures according to **KT-22** with the requirement that samples are to be submitted to the testing facility within 48 hours of casting. Therefore, the samples must be demolded at 24 ± 8 hours. See **5.3.** for transportation requirements.

NOTE: If desired, labeling to samples as outlined in **6.4.** can be performed at the time of demolding provided that the samples are still processed according to **5.1.**

5.2. Standard Curing: Samples will undergo standard curing according to **KT-22**. Samples are to remain in the curing environment until specified in section **6.3.** of this test method.

5.3. Conditioning of cores: Cores from in-situ structures will be obtained at 21 ±1 days. Cores are to be placed in the curing environment according to **5.2.** and remain there for a minimum of six days until testing is performed.

5.4. Transporting samples: Whenever samples are to be transported at any time after demolding, they are to be wrapped in saturated towels, placed in sealed plastic bags and delivered to their destination. Upon arrival at destination, samples are to be removed from bags and placed back in suitable curing environment within 30 minutes of arrival.

If samples are demolded at a location other than the testing facility, samples must be demolded and transported to the testing facility and placed back in the curing environment within 48 hours of casting. If samples are to be moved a second time after 28 day testing has occurred, samples must be transported within 72 hours from when they were removed from the curing environment.

NOTE: If these procedures are not followed and samples are allowed to dry out at any point during the curing process, this can result in an invalid test.

6. PROCEDURE

NOTE: Testing is scheduled at 28 days. However, as this is a nondestructive test and is likely to be run on samples cast for other testing purposes, resistivity testing shall occur as close to 28 days as possible before the sample is altered in any way for a different test; i.e., resistivity testing will occur on day 27 or 28 before the samples are tested for strength, **KT-76**. The samples are to be tested no earlier than 27 days, or no later than 32 days of age. Therefore, samples tested for **KT-73** cannot be used for surface resistivity testing.

6.1. At the beginning of each day of testing, calibrate the unit using the test strip provided by the manufacturer. Foam pads located on each probe tip must be saturated before and during calibration and testing. If unit does not display correct values during calibration check the following: ensure foam pads are saturated, turn off and restart the unit, then contact KDOT Research personnel for further advice.

6.2. During the test, the air temperature around the specimens shall be maintained in the range of 68 to 77°F (20 to 25°C). As the unit is portable, testing the specimens in the room they are stored in is ideal.

6.3. Remove the specimens from curing environment, blot off excess water to SSD condition, and transfer specimen to specimen holder. If samples are stored in lime-saturated water storage tanks, clean off excess lime residue from sample prior to testing. If several samples are to be tested, be sure that the samples are not allowed to dry out excessively before completion of the testing. It is recommended that only one set of three samples is removed from the curing environment at any given time.

6.4. Make four indelible marks on the top (finished) circular face of the specimen marking the 0, 90, 180, and 270 degree points of the circumference of the circle. Randomly assign one of the marks as 0°, then rotate either clockwise or counterclockwise and assign the next mark 90°, and so on. Extend the marks into the longitudinal sides of the specimens. On the longitudinal sides mark the center of the longitudinal length of the specimen in order to use as a visual reference during testing. (Figure 1)

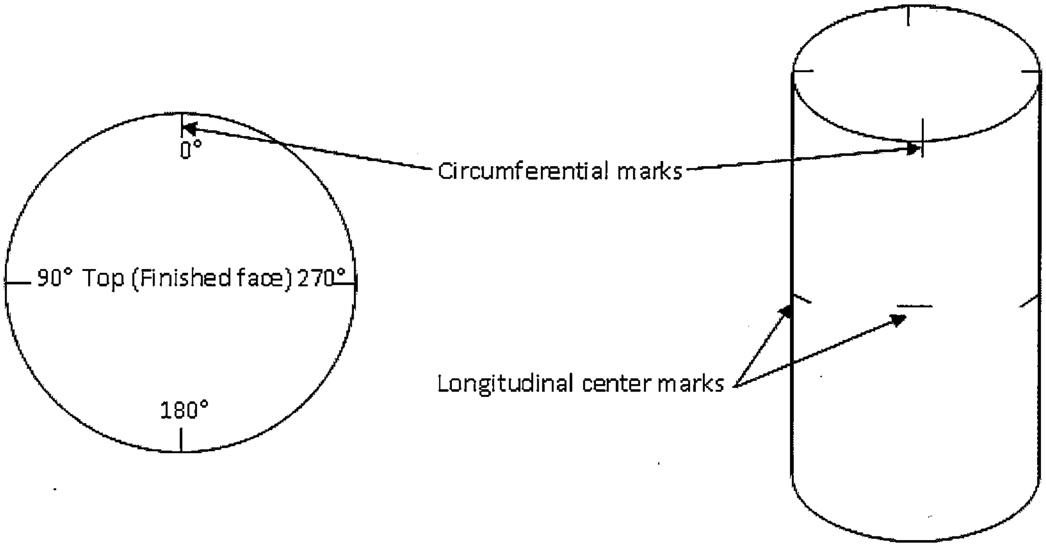


Figure 1: Specimen Marking

6.5. Place the meter longitudinally on the side of the specimen at the 0 degree mark. Center the meter longitudinally on the specimen by making sure the longitudinal center mark on the specimen is equidistant between the two inner probes (Figure 2). Make sure all the points of the array probe are in contact with the concrete. Contact with the specimen will automatically induce a reading on the display screen. Wait until a stable reading is obtained (usually 3 to 5 seconds), and record the resistivity measurement on the testing form to the nearest 0.1 kΩ-cm. A reading is considered unstable if it drifts by more than 1 kΩ-cm. Negative, unstable or obviously erroneous readings are indicative of problems with the instrument, the probe array, or specimen, and need to be addressed before proceeding.

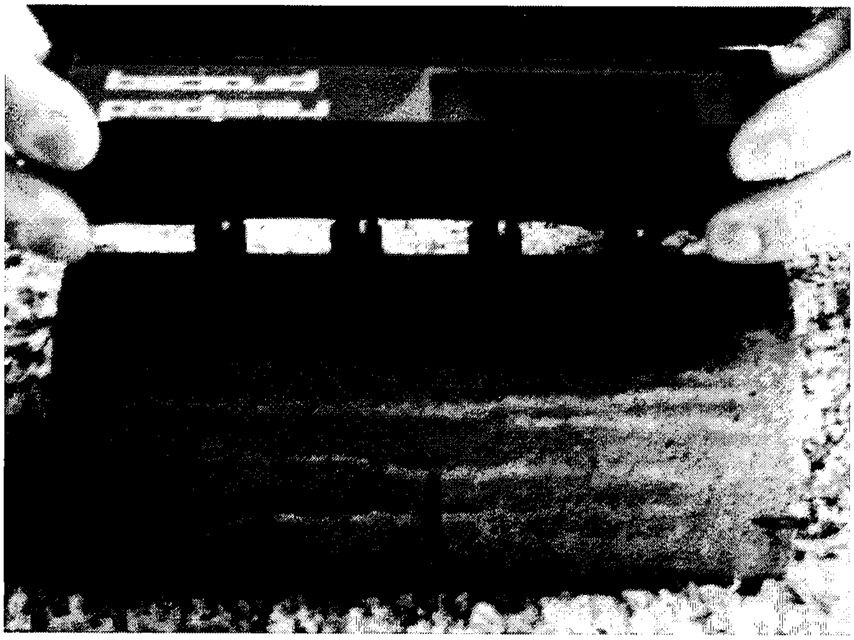


Figure 2: Location of unit during testing

6.6. Repeat step **6.5** for the 90, 180, and 270 degree marks.

6.7. Repeat steps **6.5** and **6.6** for the same specimen for a total of eight readings.

6.8. Repeat steps **6.5** to **6.7** for the remaining two specimens in the sample set.

7. CALCULATION

7.1. Calculate an average resistivity for each specimen.

7.2. Calculate an average resistivity for the set of samples by averaging the average resistivity readings **(7.1)** of the three specimens tested.

7.3. Apply the proper correction factor to the average result from **7.2.** If specimens were cured in lime-saturated water, multiply set average by 1.1. If specimens were cured in a moist room, multiply set average by 1.0. Report the final resistivity to the nearest 0.1 kΩ-cm.

8. REPORT

8.1. Report the results as required by the Contract Documents with the addition of the following information:

8.1.1. Source of core or cylinder, in terms of the particular station the core or cylinder represents.

8.1.2. CMS or equivalent identification number of core or cylinder.

8.1.3. CMS or equivalent mix design number.

8.1.4. Date cast.

8.1.5. Date samples were demolded or cores were taken.

8.1.6. Min/Max temperature during first 24 hrs (if known).

8.1.7. Date of surface resistivity testing.

8.1. 8. Description of specimen, including presence and location of reinforcing steel, presence and thickness of overlay, and presence and thickness of surface treatment.

8.1.9. Curing history of specimen.

8.1.10. Unusual specimen preparation, for example, removal of surface treatment or sulfur capping.

8.1.11. If sample is a core, report the diameter and length of sample.

8.1.12. Test results, reported as the surface resistivity measured from **7.3**.

01-14-14 C&M (JW) Typographical Changes
Mar-14 Letting

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, 2007 EDITION

Delete the entire SECTION 1102 and replace with the following:

SECTION 1102

AGGREGATES FOR CONCRETE NOT PLACED ON GRADE

1102.1 DESCRIPTION

This specification is for coarse aggregates, intermediate aggregates, fine aggregates, mixed aggregates (both coarse and fine material) and miscellaneous aggregates for use in construction of concrete not placed on grade.

For Intermediate Aggregates and Mixed Aggregates, consider any aggregate with 30% or more retained on the No. 8 sieve to be Coarse Aggregate.

1102.2 REQUIREMENTS

a. Coarse Aggregates for Concrete.

(1) Composition. Provide coarse aggregate that is crushed or uncrushed gravel or crushed stone. (Consider limestone, calcite cemented sandstone, rhyolite, quartzite, basalt and granite as crushed stone). Mixtures utilizing siliceous aggregate not found on PQL 3.1 will require supplemental cementitious materials to prevent Alkali Silica Reactions. Provide the results of mortar expansion tests of ASTM C 1567 using the project's mix design concrete materials at their designated percentages. Provide a mix with a maximum expansion of 0.10% at 16 days after casting. Provide the results to the Engineer at least 15 days before placement of concrete on the project.

(2) Quality.

(a) Provide coarse aggregates for structures (SCA) and other applications that comply with **TABLE 1102-1**.

TABLE 1102-1: QUALITY REQUIREMENTS FOR COARSE AGGREGATES

Concrete Classification	Soundness (min.)	Wear (max.)	Absorption (max.)	Acid Insol. (min.)[6]
Grade xx (AE)(SW)[1]	0.90	40	-	-
Grade xx (AE)(SA)[2]	0.90	40	2.0	-
Grade xx (AE)(AI)[3]	0.90	40	-	85
Grade xx (AE)(PB)[4]	0.90	40	3.0	-
BDWS[5]	0.95	40	-	85
All Other Grades	0.90	50	-	-

[1] Grade xx (AE)(SW) - Structural concrete with select coarse aggregate for wear.
[2] Grade xx (AE)(SA) - Structural concrete with select coarse aggregate for wear and absorption.
[3] Grade xx (AE)(AI) - Structural concrete with select coarse aggregate for wear and acid insolubility.
[4] Grade xx (AE)(PB) - Structural concrete with select aggregate for use in prestressed concrete beams.
[5] BDWS - Bridge Deck Wearing Surface.
[6] Acid Insoluble requirement does not apply to calcite cemented sandstone.

(3) Product Control.

(a) Provide Structural Coarse Aggregates that comply with **TABLE 1102-2**.

TABLE 1102-2: GRADING REQUIREMENTS FOR COARSE AGGREGATES

Type	Composition	Percent Retained - Square Mesh Sieves							
		1½"	1"	¾"	½"	⅜"	No. 4	No. 8	No. 30
SCA-2	Siliceous Gravel or Crushed Stone			0	0-35	30-70	75-100	95-100	
SCA-3	Siliceous Gravel or Crushed Stone		0	0-20		40-70		95-100	
SCA-4*	Siliceous Gravel or Crushed Stone		0	0-20				95-100	
SCA-5	Crushed Siliceous Gravel and Crushed Stone			0	0-10	15-50	85-100		

*Use with Basic Aggregate to produce Mixed Aggregate.

(b) Deleterious Substances. Maximum allowed deleterious substances by weight are:

• Material passing the No. 200 sieve (KT-2)	2.0%
• Clay lumps and friable particles (KT-7)	1.0%
• Coal (AASHTO T 113)	0.5%
• Shale or Shale-like material (KT-8)	0.5%
• Sticks (wet) (KT-35)	0.1%
• Sum of all deleterious	3.0%

(c) Uniformity of Supply. Designate or determine the fineness modulus (grading factor) according to the procedure listed in the Construction Manual Part V, Section 17 before delivery, or from the first 10 samples tested and accepted. Provide aggregate that is within ±0.20 of the average fineness modulus.

(d) Proportioning of Coarse and Fine Aggregate. Combine fine and coarse aggregates in a 50%-50% ratio by weight. Adjustments to improve workability may be made when approved by the Engineer. Use of a proven optimization method such as the ACI 302.1 method can provide adequate justification.

(4) Handling Coarse Aggregates.

(a) Segregation. Before acceptance testing, remix all aggregate segregated by transportation or stockpiling operations.

(b) Stockpiling.

- Stockpile accepted aggregates in layers 3 to 5 feet thick. Berm each layer so that aggregates do not "cone" down into lower layers.
- Keep aggregates from different sources, with different grading, or with a significantly different specific gravity separated.
- Transport aggregate in a manner that maintains uniform gradation.
- Do not use aggregates that have become mixed with earth or foreign material.
- Stockpile or bin all washed aggregate produced or handled by hydraulic methods for 12 hours (minimum) before batching. Rail shipment exceeding 12 hours is acceptable for binning provided the car bodies permit free drainage.
- Provide additional stockpiling or binning in cases of high or non-uniform moisture.

b. Intermediate Aggregate for Mixed Aggregate.

(1) Composition. Provide intermediate aggregate for mixed aggregates (IMA) that is crushed stone, natural occurring sand, or manufactured sand.

(2) Quality. Provide IMA complying with **subsection 1102.2.a.(2) or 1102.2.c.(2).**

(3) Product Control.

(a) Size Requirement. Provide IMA grading as necessary to obtain specified MA grading and any coarseness factor and workability requirements.

(b) Uniformity of Supply. Designate or determine the fineness modulus (grading factor) according to the procedure listed in the Construction Manual Part V, Section 17 before delivery, or from the first 10 samples tested and accepted. Provide aggregate that is within ±0.20 of the average fineness modulus.

(4) Handling Coarse Aggregates.

(a) Segregation. Before acceptance testing, remix all aggregate segregated by transportation or stockpiling operations.

(b) Stockpiling.

- Keep aggregates from different sources, with different gradings, or with a significantly different specific gravity separated.
- Transport aggregate in a manner that maintains uniform gradation.
- Do not use aggregates that have become mixed with earth or foreign material.
- Stockpile or bin all washed aggregate produced or handled by hydraulic methods for 12 hours (minimum) before batching. Rail shipment exceeding 12 hours is acceptable for binning provided the car bodies permit free drainage.
- Provide additional stockpiling or binning in cases of high or non-uniform moisture.

c. Fine Aggregates for Concrete.

(1) Composition.

(a) Type FA-A. Provide either singly or in combination natural occurring sand resulting from the disintegration of siliceous or calcareous rock, or manufactured sand produced by crushing predominately siliceous materials.

(b) Type FA-C. Provide crushed siliceous aggregate or chat that is free of dirt, clay, and foreign or organic material.

(2) Quality.

(a) Mortar strength and Organic Impurities. If the DME determines it is necessary, because of unknown characteristics of new sources or changes in existing sources, provide fine aggregates that comply with the following:

- Mortar Strength (Mortar Strength Test, KTMR-26). Compressive strength when combined with Type III (high early strength) cement:
  - At age 24 hours, minimum 100%*
  - At age 72 hours, minimum 100%*

  *Compared to strengths of specimens of the same proportions, consistency, cement and standard 20-30 Ottawa sand.
- Organic Impurities (Organic Impurities in Fine Aggregate for Concrete Test, AASHTO T 21). The color of the supernatant liquid is equal to or lighter than the reference standard solution.

(b) Provide FA-C for Multi-Layer Polymer Concrete Overlay complying with **TABLE 1102-3**.

TABLE 1102-3: QUALITY REQUIREMENTS FOR MULTI-LAYER POLYMER CONCRETE OVERLAY

Property	Requirement	Test Method
Soundness, minimum	0.92	KTMR-21
Wear, maximum	30%	AASHTO T96
Acid Insoluble Residue, minimum	55%	KTMR-28
Fine Aggregate Angularity, minimum	45	KT-50
Moisture Content, maximum	0.2%	KT-11

(3) Product Control.

(a) Size Requirements. Provide fine aggregates that comply with **TABLE 1102-4**.

TABLE 1102-4: GRADING REQUIREMENTS FOR FINE AGGREGATES FOR CONCRETE							
Type	Percent Retained-Square Mesh Sieves						
	⅜"	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
FA-A	0	0-10	0-27	15-55	40-77	70-93	90-100
FA-C	0	0	25-70	95-100	99-100	99-100	99-100

(b) Deleterious Substances.

- Type FA-A: Maximum allowed deleterious substances by weight are:
  - Material passing the No. 200 sieve (KT-2)........................2.0%
  - ....Coal (AASHTO T113)..0.5%
  - Sticks (wet) (KT-35)..0.1%
  - ....Sum of all deleterious..2.0%

(c) Uniformity of Supply. Designate or determine the fineness modulus (grading factor) according to the procedure listed in Part V, Section 17 before delivery, or from the first 10 samples tested and accepted. Provide aggregate that is within ±0.20 of the average fineness modulus.

(4) Proportioning of Coarse and Fine Aggregate. Combine Fine and Coarse aggregates in a 50%-50% ratio by weight. Adjustments to improve workability may be made when approved by the Engineer. Use of a proven optimization method such as the ACI 302.1 method can provide adequate justification.

(5) Handling and Stockpiling Fine Aggregates.

- Maintain separation between aggregates from different sources, with different gradings or with a significantly different specific gravity.
- Transport aggregate in a manner that promotes uniform grading.
- Do not use aggregates that have become mixed with earth or foreign material.
- Stockpile or bin all washed aggregate produced or handled by hydraulic methods for 12 hours (minimum) before batching. Rail shipment exceeding 12 hours is acceptable for binning provided the car bodies permit free drainage.
- Provide additional stockpiling or binning in cases of high or non-uniform moisture.

d. Mixed Aggregates for Concrete.

(1) Composition.

(a) Total Mixed Aggregate (TMA). A natural occurring, predominately siliceous aggregate from a single source that complies with the Wetting & Drying Test and grading requirements.

(b) Mixed Aggregate.

- Basic Aggregate (BA). Singly or in combination, a natural occurring, predominately siliceous aggregate that does not comply with either the Wetting & Drying Test or grading requirements of the Total Mixed Aggregate. For MA-1 or MA-2 mixes, sweetened basic aggregate must contain at least 50% basic aggregate. For Contractor optimized mixes (MA-3, MA-5 and MA-6), sweetened basic aggregate must contain at least 30% basic aggregate.
- Coarse Aggregate Sweetener. Types and proportions of aggregate sweeteners to be used with BA are listed in **TABLE 1102-5**.

TABLE 1102-5: COARSE AGGREGATE SWEETENER FOR BASIC AGGREGATE	
Type of Coarse Aggregate Sweetener	Proportion Required by Percent Weight
Crushed Sandstone*	30 (minimum)
Crushed Limestone or Dolomite*	30 (minimum)
Siliceous Aggregates Approved under **1102.2d.(2)** *	30 (minimum)
Siliceous Aggregates not Approved under **1102.2d.(2)** **	30 (maximum)

*Waive the minimum portion of Coarse Aggregate Sweetener for all BA that comply with the wetting and drying requirements for TMA. In this case, combine the BA and coarse aggregate sweetener in proportions required complying with the grading listed in **TABLE 1102-6**.

**To be used only with BA that complies with the wetting and drying requirements of TMA.

(2) Quality.

(a) Total Mixed Aggregate.

- Soundness, minimum (KTMR-21) 0.90
- Wear, maximum (AASHTO T96) 50%
- Wetting & Drying Test of Sand-Gravel Aggregate for Concrete (KTMR-23)

Concrete Modulus of Rupture:

- At 60 days, minimum ....550 psi
- At 365 days, minimum ....550 psi

Expansion:

- At 180 days, maximum 0.050%
- At 365 days, maximum 0.070%

Aggregates produced from the following general areas are exempt from the Wetting and Drying Test:

- Blue River Drainage Area.
- The Arkansas River from Sterling, west to the Colorado state line.
- The Neosho River from Emporia to the Oklahoma state line.

(b) Basic Aggregate.

- Retain 10% or more of the BA on the No. 8 sieve before adding the Coarse Aggregate Sweetener. Aggregate with less than 10% retained on the No. 8 sieve is to be considered a Fine Aggregate described in **subsection 1102.2c**. Provide material with less than 5% calcareous material retained on the ⅜ inch sieve.
- Soundness, minimum (KTMR-21) 0.90
- Wear, maximum (AASHTO T96) 50%
- Mortar strength and Organic Impurities. If the DME determines it is necessary, because of unknown characteristics of new sources or changes in existing sources, provide mixed aggregates that comply with the following:
    - Mortar Strength (Mortar Strength Test, KTMR-26). Compressive strength when combined with Type III (high early strength) cement:
    - At age 24 hours, minimum 100%*
    - At age 72 hours, minimum 100%*

    *Compared to strengths of specimens of the same proportions, consistency, cement and standard 20-30 Ottawa sand.
- Organic Impurities (Organic Impurities in Fine Aggregate for Concrete Test, AASHTO T 21). The color of the supernatant liquid is equal to or lighter than the reference standard solution.

(c) Coarse Aggregate Sweetener. Comply with SCA-4 in **subsection 1102.2a**.

(3) Product Control.

(a) Size Requirement. Provide mixed aggregates that comply with **TABLE 1102-6**.

TABLE 1102-6: GRADING REQUIREMENTS FOR MIXED AGGREGATES FOR CONCRETE

Type	Usage	Percent Retained - Square Mesh Sieves										
		1 ½"	1"	¾"	½"	⅜"	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100
MA-1	All concrete		0	0-5			20-60			76-84	90-96	
MA-2	All Concrete			0	3-15	15-30	33-50	45-66	64-80	78-90	87-96	95-100
MA-3	Optimized		0	2-12	Note[1]	Note[1]	Note[1]	Note[1]	Note[2]	Note[2]	Note[2]	95-100
MA-4	Optimized	0	2-12	Note[1]	Note[1]	Note[1]	Note[1]	Note[1]	Note[2]	Note[2]	Note[2]	95-100
MA-5	Drilled Shafts[3]		0	2-12	8 min	22-34		55-65		75 min		95-100
MA-6	Optimized for Silica Fume Modified Concrete		0	0	2-12	Note[1]	Note[1]	Note[1]	Note[2]	Note[2]	Note[2]	95-100

[1] Retain a maximum of 22% (24% for MA-6) and a minimum of 6% of the material on each individual sieve.
[2] Retain a maximum of 15% and a minimum of 6% of the material on each individual sieve.
[3] It is recommended that the aggregate gradation combine a SCA-3 or SCA-4 and an FA-A or Basic Aggregate for MA.

(b) Additional Requirements for optimized mixes.

- Actual Workability must be within ± 5 of Target Workability.

Where:
W_A = Actual Workability
W_T = Target Workability
CF = Coarseness Factor

1. Determine the Grading according to KT-2
2. Calculate the Coarseness Factor (CF) to the nearest whole number.

$$CF = \frac{+\,3/8\text{" Material \% Retained}}{+\,\#8\text{ Material \% Retained}}\,x100$$

3. Calculate the Actual Workability (W_A) to the nearest whole number as the percent material passing the #8 sieve.

$$W_A = 100 - \text{\% retained on \#8 sieve}$$

4. Calculate the Target Workability (W_T) to the nearest whole number where For 521 lbs cement per cubic yard of concrete

$$W_T = 46.14 - (CF/6)$$

For each additional 1 lb of cement per cubic yard, subtract 2.5/94 lbs from the Target Workability.

(c) Deleterious Substances. Maximum allowed deleterious substances by weight are:

- Material passing the No. 200 sieve (KT-2) 2.0%
- Clay lumps and friable particles (KT-7)...................................1.0%
- Coal (AASHTO T 113) 0.5%
- Shale or Shale-like material (KT-8)..0.5%
- Sticks (wet) (KT-35) 0.1%
- Sum of all deleterious..3.0%

(d) Uniformity of Supply. Designate or determine the fineness modulus (grading factor) according to the procedure listed in Part V, Section 17 before delivery, or from the first 10 samples tested and accepted. Provide aggregate that is within ±0.20 of the average fineness modulus.

(4) Handling Mixed Aggregates.

(a) Segregation. Before acceptance testing, remix all aggregate segregated by transit or stockpiling.

(b) Stockpiling.

- Maintain separation between aggregates from different sources, with different gradings or with a significantly different specific gravity.
- Transport aggregate in a manner that promotes uniform grading.
- Do not use aggregates that have become mixed with earth or foreign material.
- Stockpile or bin all washed aggregate produced or handled by hydraulic methods for 12 hours (minimum) before batching. Rail shipment exceeding 12 hours is acceptable for binning provided the car bodies permit free drainage.
- Provide additional stockpiling or binning in cases of high or non-uniform moisture.

e. Miscellaneous Aggregates for Concrete.

(1) Aggregates for Mortar Sand, Type FA-M.

(a) Composition. Provide aggregates for mortar sand, Type FA-M that is natural occurring sand.

(b) Quality.

- Mortar strength and Organic Impurities. If the DME determines it is necessary, because of unknown characteristics of new sources or changes in existing sources, provide aggregates for mortar sand, Type FA-M that comply with the following:
  - Mortar Strength (Mortar Strength Test, KTMR-26). Compressive strength when combined with Type III (high early strength) cement:
    - At age 24 hours, minimum 100%*
    - At age 72 hours, minimum 100%*

    * Compared to strengths of specimens of the same proportions, consistency, cement and standard 20-30 Ottawa sand.
  - Organic Impurities (Organic Impurities in Fine Aggregate for Concrete Test, AASHTO T 21). The color of the supernatant liquid is equal to or lighter than the reference standard solution.

(c) Product Control.

- Size Requirements. Provide aggregates for mortar sand, Type FA-M that comply with **TABLE 1102-7**.

TABLE 1102-7: GRADING REQUIREMENTS FOR MORTAR SAND

Type	Percent Retained - Square Mesh Sieves						
	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	Gradation Factor
FA-M	0	0-2	0-30	20-50	50-75	90-100	1.70-2.50

Deleterious Substances. Maximum allowed deleterious substances by weight are:

- Material passing the No. 200 sieve (KT-2) 2.0%
- Clay lumps and friable material (KT-7) 1.0%
- Coal (AASHTO T 113) 0.5%
- Sticks (wet) (KT-35) 0.1%
- Sum of all deleterious 2.5%

(2) Modified Lightweight Aggregates.

(a) Composition. Provide a modified lightweight aggregate produced from a uniform deposit of raw material combined with FA-A **subsection 1102.2c**.

(b) Quality.

- Soundness, minimum (KTMR-21) 0.90
- Loss on Ignition...5%

(c) Product Control.

- Size Requirements. Provide modified lightweight aggregates that comply with **TABLE 1102-8**.

TABLE 1102-8: GRADING REQUIREMENTS FOR MODIFIED LIGHTWEIGHT AGGREGATES

Type	Percent Retained - Square Mesh Sieves					
	¾"	½"	⅜"	No. 4	No. 8	No. 16
Grade 1	0	0-10	30-60	85-100	95-100	
Grade 2		0-2	0-30	20-50	50-75	90-100

- Deleterious Substances.
  - Organic Impurities (Organic Impurities in Fine Aggregate for Concrete Test, AASHTO T 21). The color of the supernatant liquid is equal to or lighter than the reference standard solution.
- Unit Weight (dry, loose weight) (max.)....................................1890 lbs/cu yd

(d) Concrete Making Properties. Drying shrinkage of concrete specimens prepared with modified lightweight aggregate and FA-A proportioned as shown in the Contract Documents can not exceed 0.07%.

(e) Uniformity of Supply. Designate or determine the fineness modulus (grading factor) according to procedure listed in Part V, Section 17 before delivery, or from the first 10 samples tested and accepted. Provide aggregate that is within ±0.20 of the average fineness modulus.

(f) Proportioning Materials. Submit mix designs for concrete using modified lightweight aggregate to Materials and Research for approval prior to use.

(g) Stockpiling

- Stockpile accepted aggregates in layers 3 to 5 feet thick. Berm each layer so that aggregates do not "cone" down into lower layers.
- Keep aggregates from different sources, with different gradings or with a significantly different specific gravity separated.
- Transport aggregate in a manner that promotes uniform gradation.
- Do not use aggregates that have become mixed with earth or foreign material.
- Stockpile or bin all washed aggregate produced or handled by hydraulic methods for 12 hours (minimum) before batching. Rail shipment exceeding 12 hours is acceptable for binning, provided the car bodies permit free drainage.
- Provide additional stockpiling or binning in cases of high or non-uniform moisture.

1102.3 TEST METHODS

Test aggregates according to the applicable provisions of **SECTION 1115**.

1102.4 PREQUALIFICATION

Aggregates for concrete must be prequalified according to **subsection 1101.4**.

1102.5 BASIS OF ACCEPTANCE

The Engineer will accept aggregates for concrete base on the prequalification required by this specification and **subsection 1101.5**.

DOUGLAS COUNTY ZONING & CODES DEPARTMENT
MEMORANDUM

TO: **Board of County Commissioners**
SUBJECT: ZTBU-2014-0002, Temporary Business Permit for a Concrete Batch Plant, to be located south and east of where the Mary's Lake caretaker's house was located at1535 N 1300 Road, Lawrence, KS
DATE: March 19th, 2014 , PAGE 2 CONDITIONS REVISED 03-21-14
FROM: Linda M. Finger, Planning Resource Coordinator
Jim Sherman, Director of Zoning & Codes

BACKGROUND:

Tyler Myers, with Emery Sapp & Sons Inc.(ESS) , has submitted an application for a Temporary Business Permit for the location of a Concrete Batch Plant on a site directly west of the existing 31st/N 1300 Road right-of-way located approximately ¼ mile east of Haskell Avenue/E 1500 Rd. Approval is requested for approximately a 32 month period, from March 20th, 2014 through November 30th, 2016. The site covers three properties; two held outright by KDOT and the third (Asphalt Land LLC) on which KDOT holds a permanent (use) easement.

The concrete batch plant is specifically to serve the needs of the contractor (ESS) in completing the South Lawrence Trafficway (SLT) and 31st Street extension east from Haskell Avenue/E 1500 Road to just east of O'Connell Road/E 1600 Road.

APPLICABLE REGULATIONS:

Temporary Business Uses may be permitted in any zoning district upon review and finding by the Board of County Commissioners that the proposed use is in the public interest [re: section 12-319-5]. In making this determination, the Board is required to consider four factors:

1. the intensity and duration of the use,
2. the traffic that can be expected to be generated by the use,
3. the applicant's plans for dealing with sanitation and other public health and safety issues, and
4. other factors which the Board, in its discretion, determines will affect the public's health, safety and welfare.

Temporary business uses are enumerated in section 12-319-5.01.b. The specific use requested of a temporary batch plant falls in the use category of, *"1) Batching or rock crushing plant, including concrete or asphalt."*

Typical application procedure requires an application be submitted a minimum of 28 days prior to the commencement date. A complete application was received on February 18, 2014.

The application is required to be accompanied by a plan showing the location of the temporary business use (concrete batch plant) and to provide an explanation of the proposed activities.

A summary of the activities submitted with the application follows:

- Dust Control & Road Maintenance: These activities are covered under KDOT Specifications, which are part of the KDOT Contract Emery Sapp & Sons Inc.(ESS), executed with KDOT after they were awarded the highway contract. [A copy of the relevant sections to dust control and road maintenance are attached as an addendum to this report.]
- Health Code: The Contractor's office is the building directly west of this batch plant site (the old LRM office building). Water and restrooms are available in this building for employees.

[The applicant indicated there will also be drinking water and portable toilets on the batch plant site. These are not shown on the site plan and need to be provided.]

- Lighting: The applicant has indicated there will be security lighting; the site plan will need to be revised to provide locations, type of lighting and direction of lighting. [Specific locations of security lighting are not shown on the site plan and need to be shown. The Zoning Regulations require lighting be directed down and away from adjacent properties to prevent light trespass onto adjacent properties and rights-of-way.]
- Security: There will be security fencing along the perimeter and gates that will be locked during hours when the batch plant is not in operation. There will also be security cameras on-site. [None of this is shown on the site plan. The plan needs to be revised to show these elements.]
- Township Fire Dept.: Notification is required to be given to the Wakarusa Fire Department and the Douglas County Emergency Preparedness Coordinator regarding the concrete plant's location and startup date. Staff can provide notification of the approval, location and operation dates. The applicant will need to contact the Wakarusa Fire Department and it would be a good idea to also contact the Lawrence-Douglas County Fire and Medical Department with information as to the location, operation dates, and emergency access to the site during non-business hours.
- Liability Insurance: A copy of Emery Sapp & Sons Inc. general liability & property insurance for this site will need to be on file with the Douglas County Zoning & Codes Department before operation begins.

* [*Notations in purple above are applicant's responses*.]

Public notice of the temporary business use was mailed to property owners within 1000' on February 27, 2014. The Zoning & Codes Department has received no inquiries or calls in response to the notice sent.

A public hearing is required to be held by the Board of County Commissioners on the temporary business permit application in accordance with section 12-319-5.01.f. The Commission may approve or deny the permit. If the permit is approved, the action the Commission takes need to include the **effective time period for the permit and all conditions under which the permit is granted**.

A Temporary Business Permit is issued to the applicant making the request. It is not assignable to another part without the Commission's consent [re:-12-391-5.01.g]

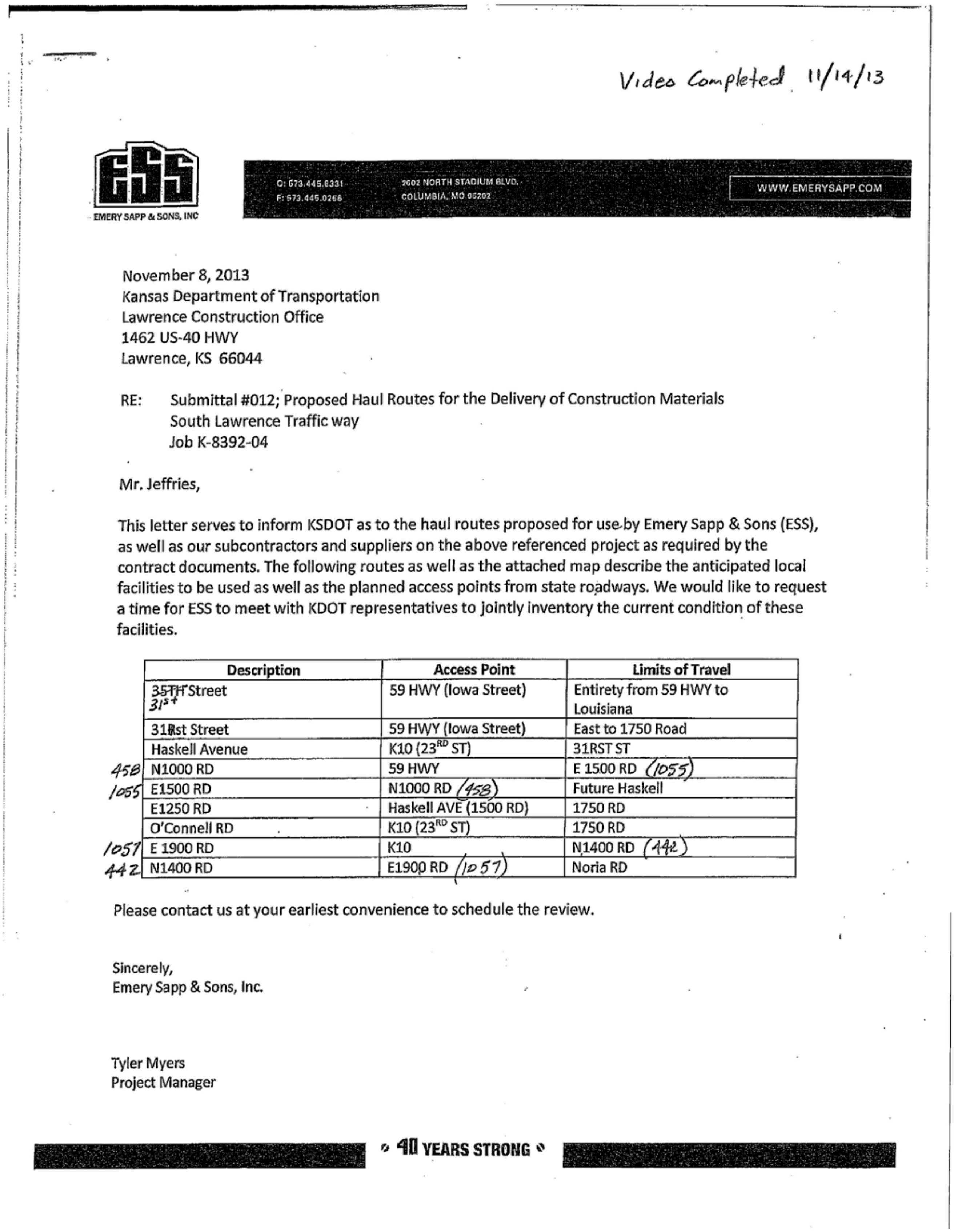
STAFF RECOMMENDATION:

Approval of the Temporary Business Permit for the location of a temporary concrete batch plant located at 1535 N 1300 Road, Lawrence, KS, for approximately 32 months, March 20th, 2014 through November 30th, 2016, subject to the following conditions:

- **A copy of the KDHE permit approval for air pollution for the operation of the equipment,**
- **A copy of the General Liability & Property Insurance covering this site showing the County as a party held harmless from claims.**
- **A dust control plan, approved by the County Engineer, is filed with the Zoning & Codes office. A portion of the management plan will include the use of magnesium chloride.**
- **Hours of operation will be dusk to dawn with the ability to seek up to 5 administrative approvals (by the Director of Zoning & Codes) for emergency situations per 12 month period, with any additional emergency situations requiring County Commission approval.**
- **Security lighting turned off when the plant is not in operation.**

**Please note an electrical permit is required for temporary power pole hook-up.*

ADDENDUM FOR DUST CONTROL AND ROAD MAINTENANCE



Video Completed 11/14/13

EMERY SAPP & SONS, INC

O: 573.445.8331
F: 573.445.0266

2602 NORTH STADIUM BLVD.
COLUMBIA, MO 65202

WWW.EMERYSAPP.COM

November 8, 2013
Kansas Department of Transportation
Lawrence Construction Office
1462 US-40 HWY
Lawrence, KS 66044

RE: Submittal #012; Proposed Haul Routes for the Delivery of Construction Materials
South Lawrence Traffic way
Job K-8392-04

Mr. Jeffries,

This letter serves to inform KSDOT as to the haul routes proposed for use by Emery Sapp & Sons (ESS), as well as our subcontractors and suppliers on the above referenced project as required by the contract documents. The following routes as well as the attached map describe the anticipated local facilities to be used as well as the planned access points from state roadways. We would like to request a time for ESS to meet with KDOT representatives to jointly inventory the current condition of these facilities.

	Description	Access Point	Limits of Travel
	~~35TH~~ Street 31st	59 HWY (Iowa Street)	Entirety from 59 HWY to Louisiana
	31Rst Street	59 HWY (Iowa Street)	East to 1750 Road
	Haskell Avenue	K10 (23^{RD} ST)	31RST ST
458	N1000 RD	59 HWY	E 1500 RD (1055)
1055	E1500 RD	N1000 RD (458)	Future Haskell
	E1250 RD	Haskell AVE (1500 RD)	1750 RD
	O'Connell RD	K10 (23^{RD} ST)	1750 RD
1057	E 1900 RD	K10	N1400 RD (442)
442	N1400 RD	E1900 RD (1057)	Noria RD

Please contact us at your earliest convenience to schedule the review.

Sincerely,
Emery Sapp & Sons, Inc.

Tyler Myers
Project Manager

40 YEARS STRONG

KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, EDITION 2007

Delete SECTION 804 and replace with the following:

SECTION 804

MAINTENANCE AND RESTORATION OF HAUL ROADS

804.1 DESCRIPTION

Maintain and restore public roads used as haul roads for construction materials.

For the purpose of this specification and when the bid item is included in the contract documents, a haul road is any public road in Kansas, excluding State highways over which material is hauled for the construction of the project. The most direct route to the nearest state highway that is used for hauling commercial material into or from a commercially established plant site is not designated as part of the haul road. Roads into and from quarries are not designated as part of the haul road.

When the bid item is not included in the Contract Documents, any haul road repair is subsidiary to the other items in the Contract Documents.

BID ITEM	**UNIT**
Maintenance and Restoration of Haul Roads (Set Price)	Lump Sum

804.2 MATERIALS

Provide the type of materials necessary to maintain and restore the haul road to its condition before the hauling begins. The Engineer will accept the materials used based on visual inspection at the point of usage.

804.3 CONSTRUCTION REQUIREMENTS

Provide the Engineer with a written description of the designated haul roads. The description shall include, materials being delivered, materials hauled to the project site and return routes from the project site. The Engineer will notify the owners of the roads (city and county) of the Contractor's designations.

Allow the Engineer sufficient time to inspect the designated haul roads before they are used. The Engineer, the Contractor and the owner of the roads (at their discretion) will jointly inspect the designated haul roads before they are used. The Engineer will document any deficiencies or special conditions regarding the existing roads and structures.

During the hauling operations, use only designated haul roads. Observe legal weight limits and speed limits.

Provide an adequate water supply and apply the water as needed to control dust. Control dust on active haul roads including return routes, in pits and staging areas, and on the project.

Perform preventative and repair maintenance as necessary to minimize the damage to the haul roads.

After the hauling operations are concluded, the Engineer, the Contractor and the owner of the roads (at their discretion) will jointly inspect the designated haul roads. The Engineer will review the results of the initial and final inspections, and will consider the impact of other parties that used the haul roads. Upon consideration of all these factors, the Engineer will determine the extent of restoration necessary to return the haul roads to their conditions at the time of the initial inspections.

Restore the haul roads as directed by the Engineer.

804.4 MEASUREMENT AND PAYMENT

When the Maintenance and Restoration of Haul Roads (Set Price) bid item is included in the Contract Documents, and the Contractor uses the designated haul roads, the Engineer will measure maintenance and restoration as a lump sum. This measurement for payment is made regardless of whether or not it is necessary for the Contractor to perform any maintenance or restoration. When the bid item is not included in the Contract Documents, any haul road repair is subsidiary to the other items in the Contract Documents.

If the bid item is in the contract and the Contractor does not designate any haul roads, no measurement for payment is made.

If the bid item is in the contract and the Contractor designates haul roads but does not use any, no measurement for payment is made.

If the Contractor uses haul roads (as defined in this specification) other than those designated, payment for "Maintenance and Restoration of Haul Roads (Set Price)" is forfeited. The Engineer will require that the Contractor restore the undesignated haul roads to their approximate condition before hauling to the project began. The Engineer will determine the extent of restoration necessary.

Payment for "Maintenance and Restoration of Haul Roads (Set Price)" at the contract unit price is full compensation for the specified work.

11-13-13 LP
Feb-14 Letting

DOUGLAS COUNTY ZONING & CODES DEPARTMENT
MEMORANDUM

TO:	**Board of County Commissioners**
SUBJECT:	ZTBU-2014-0002, Temporary Business Permit for a Concrete Batch Plant, to be located south and east of where the Mary's Lake caretaker's house was located at1535 N 1300 Road, Lawrence, KS
DATE:	March 19th, 2014
FROM:	Linda M. Finger, Planning Resource Coordinator Jim Sherman, Director of Zoning & Codes

BACKGROUND:

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The concrete batch plant is specifically to serve the needs of the contractor (ESS) in completing the South Lawrence Trafficway (SLT) and 31st Street extension east from Haskell Avenue/E 1500 Road to just east of O'Connell Road/E 1600 Road.

APPLICABLE REGULATIONS:

Temporary Business Uses may be permitted in any zoning district upon review and finding by the Board of County Commissioners that the proposed use is in the public interest [re: section 12-319-5]. In making this determination, the Board is required to consider four factors:

1. the intensity and duration of the use,
2. the traffic that can be expected to be generated by the use,
3. the applicant's plans for dealing with sanitation and other public health and safety issues, and
4. other factors which the Board, in its discretion, determines will affect the public's health, safety and welfare.

Temporary business uses are enumerated in section 12-319-5.01.b. The specific use requested of a temporary batch plant falls in the use category of, *"1) Batching or rock crushing plant, including concrete or asphalt.'"*

Typical application procedure requires an application be submitted a minimum of 28 days prior to the commencement date. A complete application was received on February 18, 2014.

The application is required to be accompanied by a plan showing the location of the temporary business use (concrete batch plant) and to provide an explanation of the proposed activities.

A summary of the activities submitted with the application follows:

- Dust Control & Road Maintenance: These activities are covered under KDOT Specifications, which are part of the KDOT Contract Emery Sapp & Sons Inc.(ESS), executed with KDOT after they were awarded the highway contract. [A copy of the relevant sections to dust control and road maintenance are attached as an addendum to this report.]

- Health Code: The Contractor’s office is the building directly west of this batch plant site (the old LRM office building). Water and restrooms are available in this building for employees. [The applicant indicated there will also be drinking water and portable toilets on the batch plant site. These are not shown on the site plan and need to be provided.]
- Lighting: The applicant has indicated there will be security lighting; the site plan will need to be revised to provide locations, type of lighting and direction of lighting. [Specific locations of security lighting are not shown on the site plan and need to be shown. The Zoning Regulations require lighting be directed down and away from adjacent properties to prevent light trespass onto adjacent properties and rights-of-way.]
- Security: There will be security fencing along the perimeter and gates that will be locked during hours when the batch plant is not in operation. There will also be security cameras on-site. [None of this is shown on the site plan. The plan needs to be revised to show these elements.]
- Township Fire Dept.: Notification is required to be given to the Wakarusa Fire Department and the Douglas County Emergency Preparedness Coordinator regarding the concrete plant’s location and startup date. Staff can provide notification of the approval, location and operation dates. The applicant will need to contact the Wakarusa Fire Department and it would be a good idea to also contact the Lawrence-Douglas County Fire and Medical Department with information as to the location, operation dates, and emergency access to the site during non-business hours.
- Liability Insurance: A copy of Emery Sapp & Sons Inc. general liability & property insurance for this site will need to be on file with the Douglas County Zoning & Codes Department before operation begins.

* [*Notations in purple above are applicant’s responses*.]

Public notice of the temporary business use was mailed to property owners within 1000’ on February 27, 2014. The Zoning & Codes Department has received no inquiries or calls in response to the notice sent.

A public hearing is required to be held by the Board of County Commissioners on the temporary business permit application in accordance with section 12-319-5.01.f. The Commission may approve or deny the permit. If the permit is approved, the action the Commission takes need to include the **effective time period for the permit and all conditions under which the permit is granted**.

A Temporary Business Permit is issued to the applicant making the request. It is not assignable to another part without the Commission’s consent [re:-12-391-5.01.g]

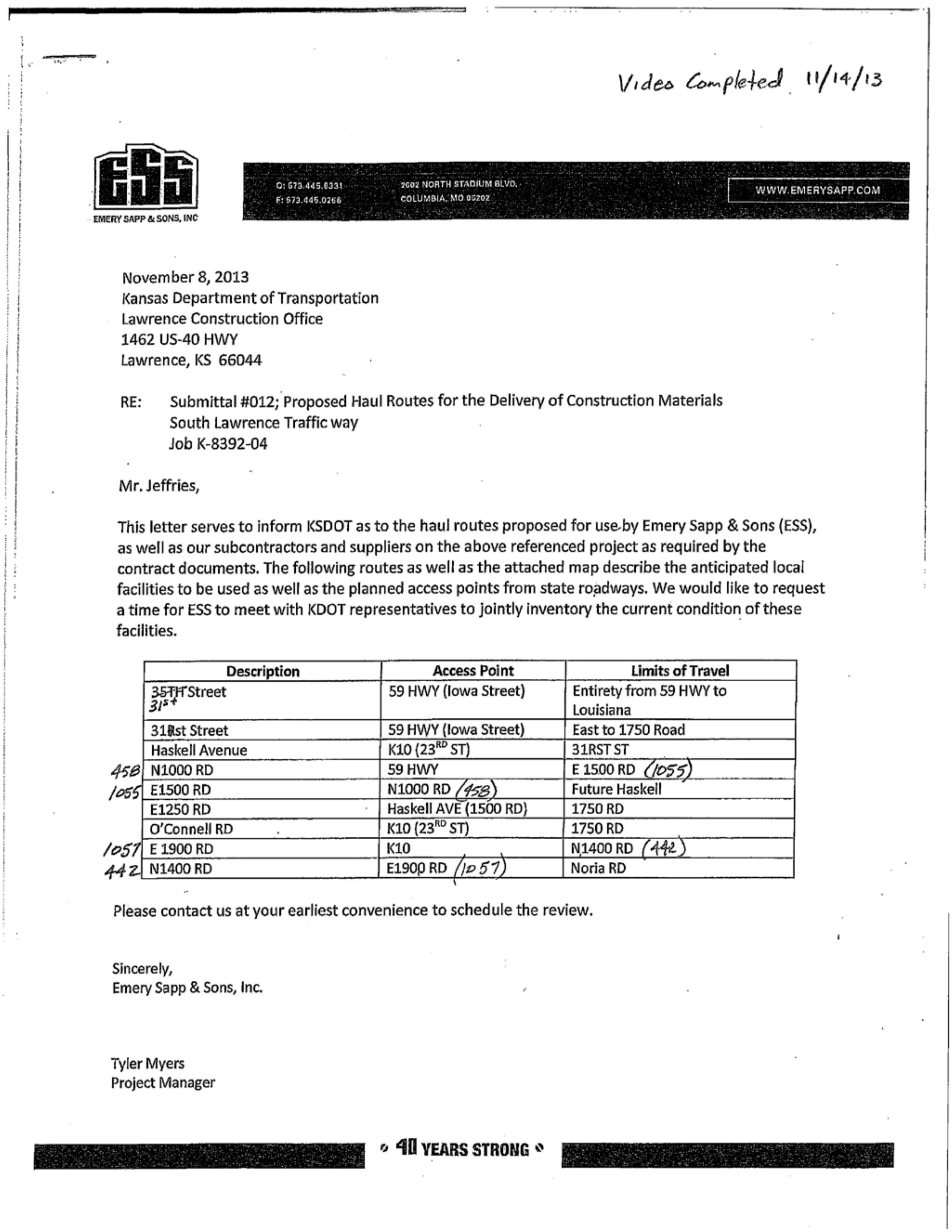
STAFF RECOMMENDATION:

Approval of the Temporary Business Permit for the location of a temporary concrete batch plant located at 1535 N 1300 Road, Lawrence, KS, for approximately 32 months, March 20th, 2014 through November 30th, 2016, subject to the following conditions:

- **~~A revised site plan showing the missing information (portable toilets, drinking water, lighting, temporary power pole, & security fencing) noted in the staff review~~, [***condition met on 03-18-14***]**
- **A copy of the KDHE permit approval for air pollution for the operation of the equipment,**
- **A copy of the General Liability & Property Insurance covering this site showing the County as a party held harmless from claims.**

**Please note an electrical permit is required for temporary power pole hook-up.*

ADDENDUM FOR DUST CONTROL AND ROAD MAINTENANCE



Video Completed 11/14/13

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November 8, 2013
Kansas Department of Transportation
Lawrence Construction Office
1462 US-40 HWY
Lawrence, KS 66044

RE: Submittal #012; Proposed Haul Routes for the Delivery of Construction Materials
South Lawrence Traffic way
Job K-8392-04

Mr. Jeffries,

This letter serves to inform KSDOT as to the haul routes proposed for use by Emery Sapp & Sons (ESS), as well as our subcontractors and suppliers on the above referenced project as required by the contract documents. The following routes as well as the attached map describe the anticipated local facilities to be used as well as the planned access points from state roadways. We would like to request a time for ESS to meet with KDOT representatives to jointly inventory the current condition of these facilities.

Description	Access Point	Limits of Travel
~~35TH~~ 31st Street	59 HWY (Iowa Street)	Entirety from 59 HWY to Louisiana
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Haskell Avenue	K10 (23RD ST)	31RST ST
458 N1000 RD	59 HWY	E 1500 RD (1055)
1055 E1500 RD	N1000 RD (458)	Future Haskell
E1250 RD	Haskell AVE (1500 RD)	1750 RD
O'Connell RD	K10 (23RD ST)	1750 RD
1057 E 1900 RD	K10	N1400 RD (442)
442 N1400 RD	E1900 RD (1057)	Noria RD

Please contact us at your earliest convenience to schedule the review.

Sincerely,
Emery Sapp & Sons, Inc.

Tyler Myers
Project Manager

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When the bid item is not included in the Contract Documents, any haul road repair is subsidiary to the other items in the Contract Documents.

BID ITEM	**UNIT**
Maintenance and Restoration of Haul Roads (Set Price)	Lump Sum

804.2 MATERIALS

Provide the type of materials necessary to maintain and restore the haul road to its condition before the hauling begins. The Engineer will accept the materials used based on visual inspection at the point of usage.

804.3 CONSTRUCTION REQUIREMENTS

Provide the Engineer with a written description of the designated haul roads. The description shall include, materials being delivered, materials hauled to the project site and return routes from the project site. The Engineer will notify the owners of the roads (city and county) of the Contractor's designations.

Allow the Engineer sufficient time to inspect the designated haul roads before they are used. The Engineer, the Contractor and the owner of the roads (at their discretion) will jointly inspect the designated haul roads before they are used. The Engineer will document any deficiencies or special conditions regarding the existing roads and structures.

During the hauling operations, use only designated haul roads. Observe legal weight limits and speed limits.

Provide an adequate water supply and apply the water as needed to control dust. Control dust on active haul roads including return routes, in pits and staging areas, and on the project.

Perform preventative and repair maintenance as necessary to minimize the damage to the haul roads.

After the hauling operations are concluded, the Engineer, the Contractor and the owner of the roads (at their discretion) will jointly inspect the designated haul roads. The Engineer will review the results of the initial and final inspections, and will consider the impact of other parties that used the haul roads. Upon consideration of all these factors, the Engineer will determine the extent of restoration necessary to return the haul roads to their conditions at the time of the initial inspections.

Restore the haul roads as directed by the Engineer.

804.4 MEASUREMENT AND PAYMENT

When the Maintenance and Restoration of Haul Roads (Set Price) bid item is included in the Contract Documents, and the Contractor uses the designated haul roads, the Engineer will measure maintenance and restoration as a lump sum. This measurement for payment is made regardless of whether or not it is necessary for the Contractor to perform any maintenance or restoration. When the bid item is not included in the Contract Documents, any haul road repair is subsidiary to the other items in the Contract Documents.

If the bid item is in the contract and the Contractor does not designate any haul roads, no measurement for payment is made.

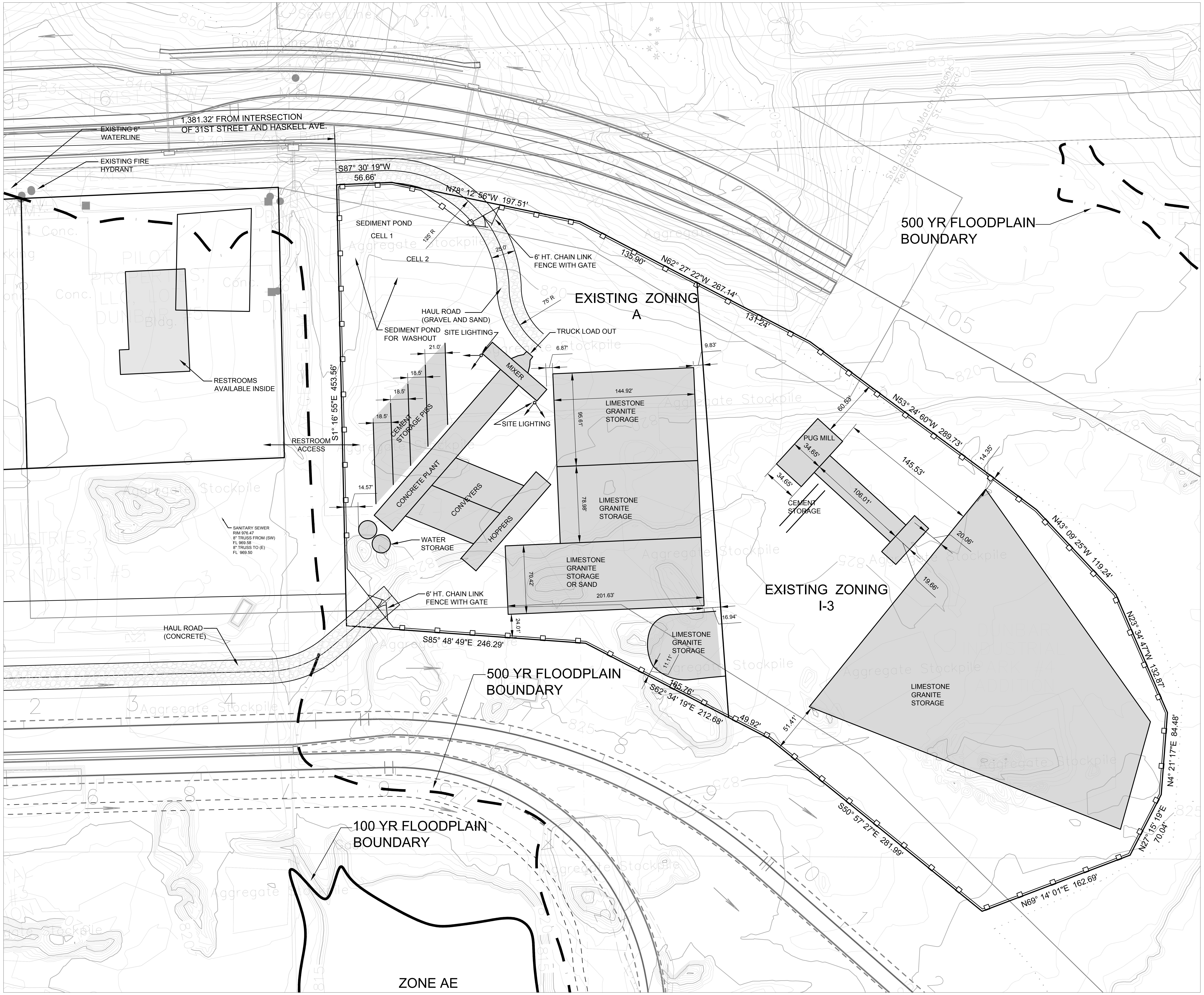
If the bid item is in the contract and the Contractor designates haul roads but does not use any, no measurement for payment is made.

If the Contractor uses haul roads (as defined in this specification) other than those designated, payment for "Maintenance and Restoration of Haul Roads (Set Price)" is forfeited. The Engineer will require that the Contractor restore the undesignated haul roads to their approximate condition before hauling to the project began. The Engineer will determine the extent of restoration necessary.

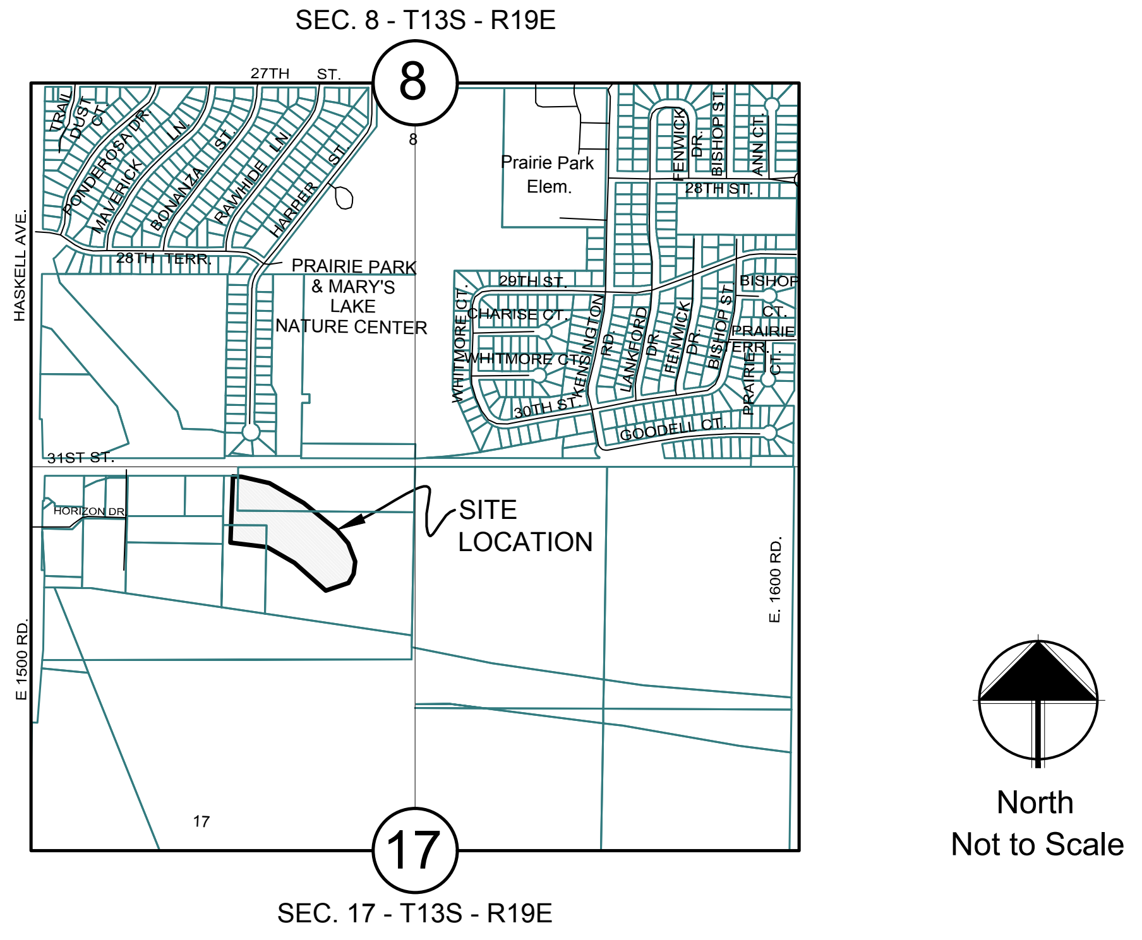
Payment for "Maintenance and Restoration of Haul Roads (Set Price)" at the contract unit price is full compensation for the specified work.

11-13-13 LP
Feb-14 Letting

FILE NAME: R:\20133039\CAD\Planning\SP\132039TUP-SP.dwg LAST SAVED BY: Alan Mackey SAVED DATE: 3/17/2014 11:56 AM PLOTTED: 3/17/2014 11:57 AM



Location Map



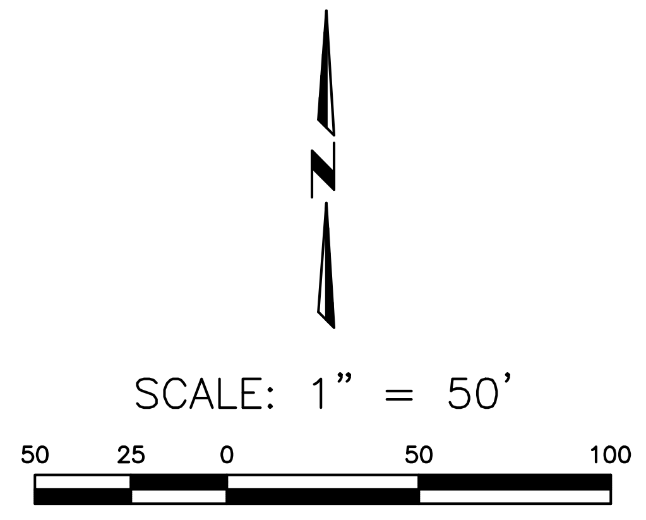
General Notes

OWNER:	KANSAS DEPARTMENT OF TRANSPORTATION 700 SW HARRISON STREET, 14TH FLOOR TOPEKA, KANSAS 66603-3754
CONTRACTOR:	EMERY SAPP & SONS INC. 140 WALNUT STREET KANSAS CITY, MISSOURI 64106
LAND PLANNER/ ENGINEER:	LANDPLAN ENGINEERING, P.A. 1310 WAKARUSA DRIVE LAWRENCE, KS 66049

1. EXISTING LAND USE: AGRICULTURAL, INDUSTRIAL
2. PROPOSED LAND USE: INDUSTRIAL (BATCH PLANT)
3. EXISTING ZONING: A - AGRICULTURAL, I-3 HEAVY INDUSTRIAL

Site Summary

GROSS SITE AREA:	351,395.81 SF / 8.07 AC
PUBLIC RIGHTS-OF-WAY:	0 SF / 0 AC
BATCH PLANT AREA:	351,395.81 SF / 8.07 AC



A TUP Site Plan for

EMERY SAPP BATCH PLANT

1535 N. 1300 ROAD

Douglas County, Kansas

LANDPLAN ENGINEERING PA
Lawrence, KS • Kansas City, MO • The Woodlands, TX
1310 Wakarusa Drive, Suite 100
Lawrence, Kansas 66049
785.843.7530(p) | 785.843.2410(f)
info@landplan-pa.com | www.landplan-pa.com

EMERY-SAPP BATCH PLANT
TEMPORARY USE PERMIT
SITE PLAN
1535 N. 1300 ROAD
DOUGLAS COUNTY, KANSAS

REV	DATE	DESCRIPTION
1	3-17-14	PER COUNTY COMMENTS

CARL L. MAURER
516

DATE: January 29, 2014
PROJECT NO.: 20133039
DESIGNED BY: LPE
DRAWN BY: ADM
CHECKED BY: CLM

ISSUE A
SHEET NO. SP-1

To the Douglas County Commissioners:

As a resident within 500 feet of the proposed cement batch plant to be operated by Emory Sapp and Sons, I am writing this letter to urge you to take into consideration the health effects from the fugitive dust generated by the proposed facility. This type of operation is synonomous with the generation of the air pollutant designate "PM-10" which is described as particulate matter with an overall diameter of less than 10 microns. Chronic exposure to this type of pollutant can have a debilitating effect on the respiratory system. This has been demonstrated in numerous studies funded by the National Institutes of Health. Furthermore, the most vulnerable to this type of pollutant are the very young and very old.

It would be my extreme preference, and that of my many neighbors also within close proximity to the proposed facility, that you deny the permit for the temporary batch plant. This request is not a matter of simple annoyance or inconvenience, but rather it is a plea for our very health. To think of the situation in another way, this type of chronic pm-10 exposure is not unlike forcing an entire neighborhood to 'sit in the smoking section'.

However, if the Commissioners do decide to approve the permit I would ask that they do so only by setting certain requirements of the operators.

- The operator apply water or some other chemical means to roadways/storage piles/loading-unloading operations and other possible sites of fugitive dust emissions and these efforts be documented. (not be needed in the event of precipitation greater than ¼ inch while operating)
- Paved roadways within and leading in and out of the facility be washed/cleaned periodically
- All trucks have dust control measures such as covers or dust suppression sytems or have water applied
- No diesel generators powering the plant
- Time of day operating restrictions (6am to 6pm)
- Days of week operating restrictions (Monday through Friday)
- Ensure that while operating the ambient impact of PM-10 at or beyond the nearest residence (500ft) not exceed 150 ug/m^3 in any 24 hour period. This can be demonstrated by maintaining a daily log of material processed and the ambient impact factor (rating) of equipment at the site (including background levels (estimated at 20 ug/m^3)
- That all equipment be in good repair and that adequate replacement parts are available so that the plant is never operating without control equipment in place (dust shrouds, filters, etc.)

Most of these requirements regarding emission control are very similar to those the operator has been subject to in other states (MO) based on that state's air pollution regulations. I have spoken with representatives of the KDHE regarding air quality permits and have found that even though many other states place strict emission controls and requirements on this type of operation, Kansas does not. Therefore, it is solely within the discretion of the Commissioners to mandate these requirements that will at least provide the residents with some minimum level of protection.

Thank you for taking the time to consider these concerns and for your service to Douglas County.

Sincerely,

Daniel Aillon
3026 Harper St.
Lawrence, KS

Long-term Exposure to PM_{10} and NO_2 in Association with Lung Volume and Airway Resistance in the MAAS Birth Cohort

Anna Mölter,[1] Raymond M. Agius,[1] Frank de Vocht,[1] Sarah Lindley,[2] William Gerrard,[3] Lesley Lowe,[4] Danielle Belgrave,[4] Adnan Custovic,[4] and Angela Simpson[4]

[1]Centre for Occupational and Environmental Health, Health Sciences Group, School of Community-Based Medicine, Manchester Academic Health Sciences Centre, The University of Manchester, Manchester, United Kingdom; [2]Department of Geography, School of Environment, Education and Development, The University of Manchester, Manchester, United Kingdom; [3]Salford Lung Study, North West e-Health, Salford, United Kingdom; [4]Manchester Academic Health Science Centre, NIHR Translational Research Facility in Respiratory Medicine, University Hospital of South Manchester NHS Foundation Trust, Wythenshawe Hospital, Manchester, United Kingdom

Background: Findings from previous studies on the effects of air pollution exposure on lung function during childhood have been inconsistent. A common limitation has been the quality of exposure data used, and few studies have modeled exposure longitudinally throughout early life.

Objectives: We sought to study the long-term effects of exposure to particulate matter with an aerodynamic diameter ≤ 10 μm (PM_{10}) and to nitrogen dioxide (NO_2) on specific airway resistance (sR_{aw}) and forced expiratory volume in 1 sec (FEV_1) before and after bronchodilator treatment. Subjects were from the Manchester Asthma and Allergy Study (MAAS) birth cohort ($n = 1,185$).

Methods: Spirometry was performed during clinic visits at ages 3, 5, 8, and 11 years. Individual-level PM_{10} and NO_2 exposures were estimated from birth to 11 years of age through a micro-environmental exposure model. Longitudinal and cross-sectional associations were estimated using generalized estimating equations and multivariable linear regression models.

Results: Lifetime exposure to PM_{10} and NO_2 was associated with significantly less growth in FEV_1 (percent predicted) over time, both before (–1.37%; 95% CI: –2.52, –0.23 for a 1-unit increase in PM_{10} and –0.83%; 95% CI: –1.39, –0.28 for a 1-unit increase in NO_2) and after bronchodilator treatment (–3.59%; 95% CI: –5.36, –1.83 and –1.20%; 95% CI: –1.97, –0.43, respectively). We found no association between lifetime exposure and sR_{aw} over time. Cross-sectional analyses of detailed exposure estimates for the summer and winter before 11 years of age and lung function at 11 years indicated no significant associations.

Conclusions: Long-term PM_{10} and NO_2 exposures were associated with small but statistically significant reductions in lung volume growth in children of elementary-school age.

Citation: Mölter A, Agius RM, de Vocht F, Lindley S, Gerrard W, Lowe L, Belgrave D, Custovic A, Simpson A. 2013. Long-term exposure to PM_{10} and NO_2 in association with lung volume and airway resistance in the MAAS birth cohort. Environ Health Perspect 121:1232–1238. http://dx.doi.org/10.1289/ehp.1205961

Introduction

Lung function is an important indicator of respiratory health and long-term survival (Hole et al. 1996). Unlike information collected through questionnaires, measured lung function is an objective health outcome that is not affected by recall or reporting bias. The respiratory tract is at risk from air pollution, because gaseous pollutants and small particles in the air are inhaled through the nose and mouth. Two air pollutants frequently studied are nitrogen dioxide (NO_2) and particulate matter (PM). Both are derived from traffic related sources, but are also generated within the home—for example, by gas cookers and cigarette smoke. Both of these pollutants have been associated with respiratory and cardiovascular morbidity and mortality (Brunekreef and Holgate 2002). Several cross-sectional and longitudinal studies have been carried out on the association between NO_2 and PM exposure and lung function in children. However, results of these studies have been disparate and conclusions inconsistent. Whereas some studies reported associations with lung volume only (Raizenne et al. 1996; Rojas-Martinez et al. 2007; Sugiri et al. 2006), others reported associations with expiratory flow only (Avol et al. 2001; Oftedal et al. 2008). Some studies reported associations with both lung volume and flow (Gauderman et al. 2000; Horak et al. 2002; Schwartz 1989), whereas others reported no associations at all (Dockery et al. 1989; Hirsch et al. 1999; Neas et al. 1991; Nicolai et al. 2003). In a recent review of studies on air pollution and lung function, Götschi et al. (2008) concluded that it was not possible to perform formal quantitative comparisons of findings because of the heterogeneity of study designs.

One limitation common to many previous studies lies in the assessment of exposure to air pollution. Most studies of the effects of air pollution on lung development in children have estimated associations with more recent air pollution exposure—the average concentration over the previous 12 months, rather than lifetime exposure or early-life exposure (Oftedal et al. 2008), and have estimated exposures based on measurements from central monitoring stations located near the child's residence, without accounting for geographical factors (Hirsch et al. 1999; Nicolai et al. 2003; Oftedal et al. 2008), indoor as well as outdoor exposures, or time–activity patterns.

We have developed a novel micro-environmental exposure model (MEEM) (Mölter et al. 2012), which allows for spatial (indoor and outdoor microenvironments) and temporal variability in pollutant concentrations (Mölter et al. 2010a, 2010b) and incorporates children's time–activity patterns to predict personal exposure. The performance of MEEM (for NO_2) was evaluated previously through a personal monitoring study of 46 12- to 13-year-old schoolchildren in Manchester, United Kingdom (Mölter et al. 2012); we found good agreement between modeled and measured NO_2 concentration (e.g., mean predictor error = –0.75; normalized mean bias factor = 0.04; normalized mean average error factor = 0.27; Spearman's rank correlation = 0.31, $p < 0.05$) This performance evaluation also demonstrated that MEEM provided better estimates of exposure

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Supplemental Material is available online (http://dx.doi.org/10.1289/ehp.1205961).

We thank the families who participate in MAAS (Manchester Asthma and Allergy Study) and all members of the MAAS study team for their tireless effort, particularly J. Nathan and M. Mycock, who carried out the data quality checks. The exposure model used in this study was partly based on the Greater Manchester air dispersion modeling study carried out by the former Atmospheric Research and Information Centre on behalf of the local authorities of Greater Manchester. Therefore, we also thank the Manchester Area Pollution Advisory Council for permitting us to access this data. Furthermore, we are very grateful to M. Ashmore, S. Dimitroulopoulou, and A. Terry for permitting us access to the INDAIR model (Dimitroulopoulou et al. 2006) and for their helpful advice on the use of this model.

MAAS has been supported by Asthma UK, The JP Moulton Charitable Foundation, and The Medical Research Council.

Portions of this work have been published in a PhD thesis submitted to the University of Manchester.

The authors declare they have no actual or potential competing financial interests.

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than central monitors or an outdoor air pollution model, which tended to overestimate personal exposure levels (Mölter et al. 2012).

The aim of the present study was to estimate the associations of modeled PM_{10} (particulate matter with an aerodynamic diameter ≤ 10 μm) and NO_2 exposure with lung function in elementary-school children enrolled in a population-based birth cohort—the Manchester Asthma and Allergy Study (MAAS). Exposures and lung function were evaluated longitudinally throughout childhood. In addition, we applied a more detailed exposure model in a cross-sectional analysis of lung function measured at 11 years of age.

Methods

Study population. The children studied were participants of MAAS, is an ongoing prospective birth cohort, which initially comprised 1,185 children of mothers who were recruited during pregnancy at two local hospitals between 1995 and 1997 (Simpson et al. 2001). Children attended review clinics at ages 3, 5, 8, and 11 years; the clinics included pulmonary function tests and skin prick tests for common inhalant and food allergens. In addition, parentally completed questionnaires were collected at each review (Custovic et al. 2002, 2004). MAAS received ethical approval by the Local Research Ethics Committee (SOU/00/258; SOU/00/259), and written informed consent was provided by the parents.

Definition of outcomes: lung function. All pulmonary function tests were performed by trained technicians at Wythenshawe Hospital, Manchester. The most informative test to measure lung function was selected for each age group (Beydon et al. 2007; Bisgaard and Klug 1995; Dab and Alexander 1976).

Specific airways resistance (sR_{aw}) was measured at ages 3, 5, 8, and 11 years, using a constant volume whole-body plethysmograph (Masterscreen Body 4.3; Erich Jaeger GmbH, Würzburg, Germany) (Lowe et al. 2002; Nicolaou et al. 2008). High values of sR_{aw} indicate poor lung function. Forced expiratory volume in 1 sec (FEV_1) was measured at ages 5, 8, and 11 years using a pneumotachograph-based spirometer (Erich Jaeger Gmbh). The protocol for measuring FEV_1 was in accordance with American Thoracic Society guidelines (American Thoracic Society 1995). All children were asymptomatic at the time of testing, and β2-agonists were withheld for at least 4 hr before testing. The test was repeated at intervals of 30 sec until three technically acceptable traces were obtained, the highest two of which were within 5% of each other. The percent predicted FEV_1 was calculated using reference equations developed by the Asthma UK Collaborative Initiative (Stanojevic et al. 2009). Postbronchodilator FEV_1 was measured when the children were 5 and 11 years of age by repeating the FEV_1 measurement 15 min after inhalation of 400 μg of albuterol. Results were analyzed as percent predicted FEV_1.

Definition of exposures: modeled PM_{10} and NO_2 exposure. The exposure estimates in this study are based on the concept of microenvironments (ME)—a defined space with a homogenous pollutant concentration (Ott 1982). MEs can represent spaces outdoors or indoors, and different methods can be used to estimate concentrations in different types of microenvironments. The microenvironmental models used in this study assumed that children spend the majority of their time in three types of MEs: home, school, and the journey between home and school.

Information on children's home and school addresses from birth to 11 years of age was collected through a parental questionnaire, completed at the age 11 review. In this questionnaire parents were asked to list the dates and addresses for all homes the child had lived in and each school the child attended, the mode of transport between each home and respective schools. These data were entered into an SQL database (MS SQL2008R2; Microsoft, Redmond, WA, USA) to create a timeline for home and school addresses from birth to 11 years of age for each child. In addition, the shortest driving route between each home and school was estimated using the network analyst extension of ArcGIS9.2 (ESRI, Redlands, CA, USA).

Figure 1 summarizes the methods used to estimate NO_2 and PM_{10} concentration in each ME. Concentrations for outdoor MEs (i.e., home outdoor ME, school outdoor ME, journey outdoor ME) were estimated using land use regression (LUR) models, as described in detail elsewhere (Mölter et al. 2010a, 2010b). In brief, LUR models were developed using estimated annual mean NO_2 and PM_{10} concentrations at 208 locations derived from an air dispersion model. The final LUR models mainly comprised traffic-related predictor variables, such as vehicle counts on major roads, and had determination coefficients (R^2) of 0.71. Performance evaluations using a set-aside data set (70 locations), and concentrations measured at automatic monitoring stations showed an acceptable level of agreement (R^2 range, 0.33–0.86). To model children's exposure from 1996 through 2008, the above LUR models were recalibrated to provide 13 annual models for PM_{10} and NO_2, respectively (Mölter et al. 2010b): Data from the air dispersion model and the United Kingdom year adjustment calculator were used to estimate annual PM_{10} and NO_2 concentrations from 1996 through 2008 at the 278 receptor sites described above. These concentrations were entered into regression analyses that included the same predictor variables used in the original LUR models. This resulted in individual models for each year; all models used the same predictor variables but generated different coefficients. A performance evaluation of these models against monitored data showed good agreement [R^2 range, 0.35–0.97; root mean square error (RMSE) range, 1.8–8.3] (Mölter et al. 2010b).

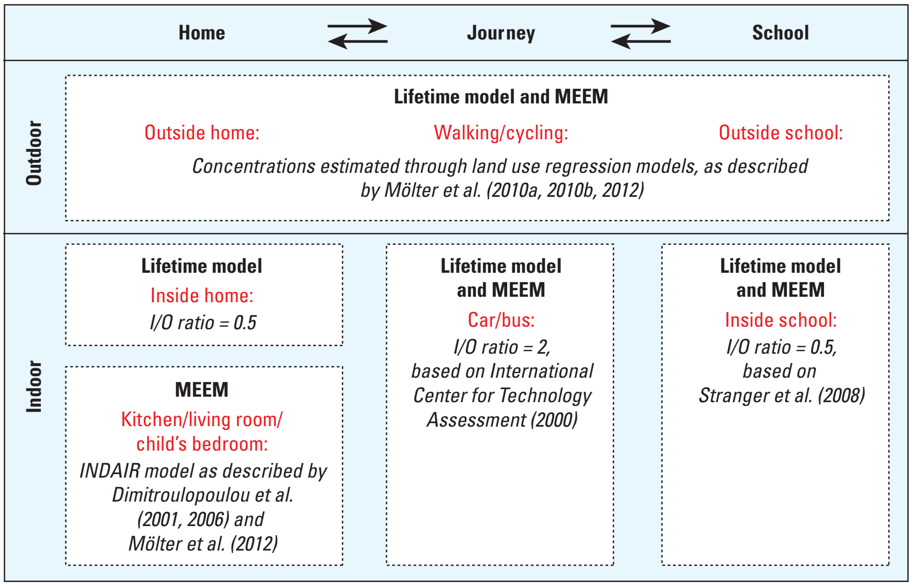

Figure 1. Outline of exposure assessment showing methods used to estimate concentrations in each microenvironment (with relevant references). The same methods were used at all time points except for the year before the age 11 review. A detailed indoor model could be used to estimate concentrations inside the kitchen, living room, and child's bedroom. Abbreviations: I/O, Indoor to outdoor ratio; MEEM, microenvironmental exposure model.

Concentrations for journey indoor MEs (i.e., inside cars or buses) and school indoor MEs were estimated based on indoor to outdoor (I/O) ratios published in the literature (International Center For Technology Assessment 2000; Stranger et al. 2008). Concentrations in the Home indoor MEs were estimated using I/O ratios or a mass balance model (INDAIR), depending on the time period being modeled (Dimitroulopoulou et al. 2006). This resulted in two slightly different models: the MEEM and the lifetime models (Figure 1).

MEEM was used to estimate each child's exposures during the summer and winter before the review visit at 11 years of age (Mölter et al. 2012). We modeled winter and summer exposures separately to capture variation in home indoor air concentrations because of seasonal differences in air exchange rates. In MEEM home kitchen ME, home living room ME, and home bedroom ME, concentrations were estimated individually using the INDAIR model, designed specifically to estimate indoor concentrations of NO_2 and PM_{10} concentrations within residential buildings in the United Kingdom (Dimitroulopoulou et al. 2001, 2006).

A parent questionnaire administered at the child's age 11 review was used to collect input parameters for the INDAIR model, such as room sizes, air exchange rates, and the presence of indoor sources of NO_2 and PM_{10}. The indoor sources included in the model were gas cooking and cigarette smoke, which are considered to be the main sources of NO_2 and PM_{10} inside homes in the United Kingdom (Berry et al. 1996; Coward et al. 2001). In addition, the questionnaire collected time–activity data used to estimate the timing and duration of time in each ME. Therefore, MEEM provided spatially resolved time-weighted exposure estimates for each child.

We evaluated the performance of MEEM using a personal monitoring study of schoolchildren (12–13 years of age) attending a local secondary school in Manchester (Mölter et al. 2012). MEEM performed well when compared with NO_2 concentrations measured with personal monitors (Ogawa passive samplers; Ogawa & Co. USA, Inc., Pompano Beach, FL, USA), with a mean prediction error of –0.75 μg/m^3. A paired analysis of measured and predicted concentrations showed no significant difference between measured concentrations and MEEM estimates (Wilcoxon's signed rank test: $z = -0.05$, $p = 0.96$).

Input parameters for the INDAIR model were available for the current (at 11 years of age) home of each child, but most children had changed residence at least once since birth. Therefore, we used a simplified lifetime model to estimate the average PM_{10} and NO_2 exposure of each child for each month from birth to 11 years. In contrast with MEEM, the lifetime model used an I/O ratio to calculate exposure inside the home, instead of using the INDAIR model, and it assumed that all children were in the school indoor ME from 0900 to 1500 hours. However, as for MEEM, outdoor ME exposures (i.e., home outdoor ME, school outdoor ME, journey outdoor ME) were estimated using LUR models, and journey indoor MEs (i.e., inside cars or buses) and school indoor MEs were estimated based on I/O ratios.

Definition of potential confounders. Potential confounding variables and covariates were identified based on previous research within MAAS and previous publications (Lowe et al. 2002, 2004; Nicolaou et al. 2008; Oftedal et al. 2008) and included sex, age, ethnicity, older siblings, sensitization, asthma or current wheeze, family history of asthma, parental smoking, parental atopy, child care attendance during the first 2 years of life, hospitalization during the first 2 years of life, presence of a gas cooker in the home, presence of a dog or cat in the home, visible signs of dampness or mold in the home, body height, body weight, body mass index, maternal age at birth, gestational age, duration of breastfeeding, Tanner stage (age 11 years only), and socioeconomic status (paternal income). In addition, average PM_{10} and NO_2 concentrations over 3 days before the child's review visit were collected from four (for PM_{10}) or five (for NO_2) urban background monitoring stations across the Greater Manchester area (Oftedal et al. 2008).

We classified children as having current wheeze based on a positive response to the question "Has your child had wheezing or whistling in the chest in the last 12 months?" and classified them as having asthma based on positive answers to at least two of the following three variables: doctor diagnosis of asthma ever; current wheeze; asthma medication during the previous 12 months, consistent with the GA^{2}LEN (Global Allergy and Asthma European Network) definition of asthma (Carlsen et al. 2006; Håland et al. 2006). At each review, potential allergic sensitization to common inhalant and food allergens was determined through skin prick tests for inhalant allergens (mites, cat, dog, mold, grass pollen, and tree pollen) and food allergens (milk, egg, and peanut). All allergens were tested at each review except for tree pollen and peanut allergens, which were tested at the age 8 and age 11 reviews only. Children were classified as having atopy, if they had at least one positive skin prick test (defined as a mean wheal diameter 3 mm greater than the negative control). Parental atopy was also established through skin prick tests, which were carried out during the recruitment stage.

Statistical analysis. All analyses were carried out with SPSS 16.0 (IBM SPSS, Chicago, IL, USA). Before all analyses, sR_{aw} was ln-transformed because it follows a log-normal distribution. FEV_1 and postbronchodilator FEV_1 were not transformed because these variables were normally distributed. Multivariable linear regression was used to cross-sectionally estimate associations of PM_{10} and NO_2 exposure during the summer and winter before children were 11 years of age (estimated by MEEM), with sR_{aw} and FEV_1 at 11 years. All potential confounders were entered individually into bivariate models with the exposure and outcome variables, and potential confounders that were significant predictors of the outcome ($p < 0.05$) were evaluated using multivariate stepwise analyses that retained only covariates that significantly predicted the outcome, or that were retained *a priori* (age and sex in all sR_{aw} models, Tanner stage for all models of outcomes at age 11). Models of FEV_1 outcomes were not adjusted for age, sex, and body height, because these factors were used to calculate the percent predicted values. Models of MEEM exposures at 11 years of age were not adjusted for cigarette smoking because information on smoking was already included in the INDAIR model.

We analyzed the association between lifetime exposure and the development of lung function using generalized estimating equations to account for the within-subject correlation of repeated measures, with the same covariates included in the cross-sectional models. Monthly exposures were averaged into the following time windows: for sR_{aw}, 0–3, 3–5, 5–8, and 5–11 years of age; for FEV_1, 0–5, 5–8, and 8–11 years of age; for FEV_1 after bronchodilator treatment, 0–5 and 5–11 years of age. For completeness, exposure estimates from the lifetime exposure model were also analyzed cross-sectionally against lung function at 3, 5, 8, and 11 years of age. For these analyses the monthly exposure estimates were averaged into the following time windows: first year of life (0–1), birth to review ages (0–3, 0–5, 0–8, 0–11 years), 1 calendar year before reviews (2–3, 4–5, 7–8, 10–11 years). The level for statistical significance was set at $p < 0.05$.

Results

Participants and descriptive data. Participant flow with numbers of individuals at each stage of the study, the number of lung function measurements collected and the number of exposure estimates available is shown in Figure 2. Descriptive statistics of the study population and the covariates included in the final models are presented in Table 1; descriptive statistics of potential confounders not included in the final models are shown in Supplemental Material, Table S1. As expected, the prevalence of atopy increased from 3 to 11 years of age, whereas the prevalence of asthma or current wheeze remained fairly constant during this time period. A complete data set of FEV_1, pollutant exposures, and covariates at two or more reviews was available for 342 children (Table 1). Children included in the longitudinal analysis of the effect of PM_{10} and NO_2 exposure on the change in FEV_1 were more likely to be female and were less likely to have asthma or wheeze in early life. By 8 years of age, there were no differences in asthma/wheeze between children with full sets of longitudinal data and those without. Table 2 summarizes the lung function measurements at each age. The mean FEV_1 increased from 1.05 L at 5 years to 2.30 L at 11 years, resembling typical values for Caucasian children of these ages (Stanojevic et al. 2009).

Exposure to pollutants. Figures S1 and S2 (Supplemental Material) describe the distribution of the exposure estimates by pollutant and exposure time window. MEEM predicted higher PM_{10} and NO_2 exposures during the winter than during the summer (see Supplemental Material, Figures S1 and S2), and it predicted a wider range of exposures than the lifetime model. The lifetime exposure estimates decreased from 0–1 to 10–11 years of age (see Supplemental Material, Figures S1 and S2), which most likely reflects the general decrease of PM_{10} and NO_2 levels in the Greater Manchester area from 1996 to 2008 (Department for Environment, Food and Rural Affairs 2009). PM_{10} and NO_2 exposures were moderately to strongly correlated in all exposure time windows (Pearson's $r = 0.59–0.89$).

Association between exposure to pollutants and sR_{aw}. The results of the cross-sectional analyses conducted at 3–11 years of age are shown in Supplemental Material, Table S2. Table S2 indicates a significant negative association between PM_{10} exposure during early life and sR_{aw} at 3 and 5 years. However, all other analyses showed no statistically significant associations. Furthermore, at 11 years there was no association between PM_{10} and NO_2 exposure (MEEM) during the summer or winter and sR_{aw} (Table 3), and there was no association between lifetime exposure and longitudinal sR_{aw}.

Association between exposure to pollutants and FEV_1. In the cross-sectional analysis at 11 years of age, there was no association between PM_{10} and NO_2 exposure (MEEM) during the summer or winter and FEV_1 percent predicted (Table 3). In contrast, the longitudinal model of lifetime exposure to pollutants and longitudinal measures of FEV_1 revealed a significant association between exposure to pollutants and the change in this

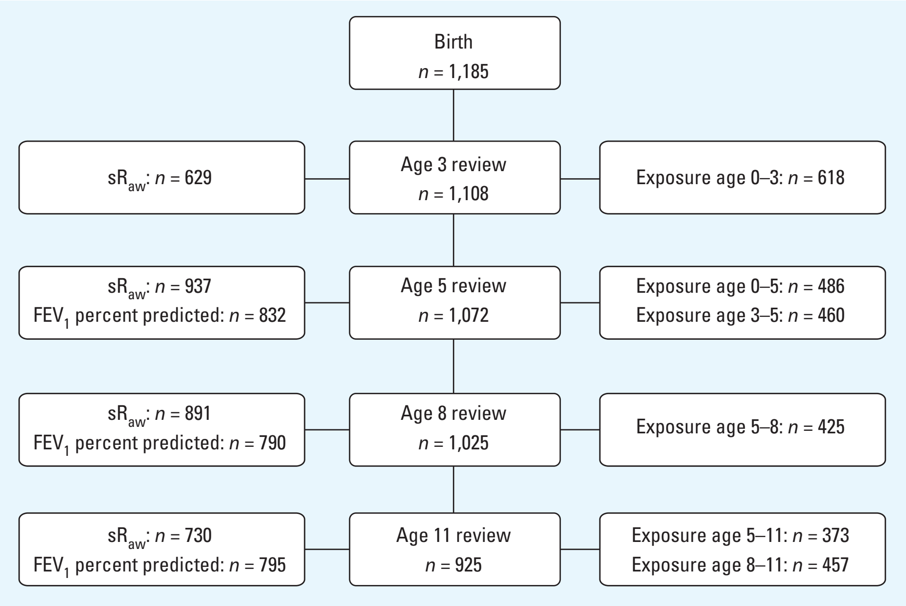

Figure 2. Flow diagram of MAAS cohort showing participation rates at each review, the number of lung function measurements collected, and the number of exposure estimates available.

Table 1. Description of study population.

	MAAS cohort at birth		Children with longitudinal FEV_1 and longitudinal exposure data		
Variable	N[a]	n[b] (%) or mean ± SD	N[a]	n[b] (%) or mean ± SD	p-Value[c]
Female sex	1,185	543 (45.8)	342	173 (50.6)	0.036
Family history of asthma	1,185	441 (37.2)	342	125 (36.5)	0.763
Child is atopic[d]					
Age 3	983	225 (22.9)	306	72 (23.5)	0.748
Age 5	963	294 (30.5)	334	94 (28.1)	0.241
Age 8	927	314 (33.9)	330	100 (30.3)	0.088
Age 11	784	281 (35.8)	332	116 (34.9)	0.652
Child has asthma or current wheeze					
Age 3	1,097	296 (27.0)	330	71 (21.5)	0.007
Age 5	1,071	297 (27.7)	341	75 (22.0)	0.004
Age 8	1,023	217 (21.2)	341	65 (19.1)	0.234
Age 11	925	214 (23.1)	341	78 (22.9)	0.886
Hospitalization during first 2 years of life for lower respiratory tract infection	1,185	109 (9.2)	342	34 (9.9)	0.573
Gas cooker in the home					
Age 1	1,028	801 (77.9)	341	270 (79.2)	0.492
Age 8	1,029	819 (79.6)	342	270 (78.9)	0.717
Age 11	930	727 (78.2)	342	267 (78.1)	0.954
Age at follow-up (years)					
Age 3	1,081	3.0 ± 0.1	326	3.0 ± 0.0	0.208
Age 5	1,044	5.0 ± 0.1	340	5.0 ± 0.1	0.008
Age 8	976	8.0 ± 0.2	339	8.0 ± 0.1	0.084
Age 11	813	11.4 ± 0.5	341	11.4 ± 0.5	0.876
Body mass index (kg/m^2)					
Age 3	1,044	16.7 ± 1.4	321	16.7 ± 1.5	0.914
Age 5	1,017	16.3 ± 1.6	339	16.4 ± 1.7	0.776
Age 8	923	17.1 ± 2.4	333	17.1 ± 2.6	0.643
Age 11	816	19.1 ± 3.4	341	19.2 ± 3.4	0.885
Short-term PM_{10} ($\mu g/m^3$) 3-day average before review visit					
Age 3	1,081	21.6 ± 7.7	326	21.0 ± 6.9	0.186
Age 5	1,044	21.5 ± 7.2	340	21.6 ± 7.2	0.910
Age 8	976	20.8 ± 6.2	339	21.0 ± 6.0	0.660
Age 11	820	19.6 ± 9.2	337	19.7 ± 9.0	0.895
Mean Tanner stage	763	2.1 ± 0.9	317	2.1 ± 0.9	0.648

[a] Total number of children. [b] Number of positive children. [c] p-Value of chi-square test or Student's t-test comparing children with longitudinal FEV_1 and exposure data against all children in the MAAS cohort at birth. [d] Determined through skin prick test, mean wheal diameter 3 mm greater than negative control for at least 1 of 9 allergens tested.

measure of lung function during childhood. PM_{10} and NO_2 exposures were associated with poorer lung function over time [PM_{10}: β = –1.37 (95% CI: –2.52, –0.23); NO_2: β = –0.83 (95% CI: –1.39, –0.28)]. Based on the average predicted FEV_1 within MAAS at 5, 8, and 11 years of 1.65 L (Table 2), the model estimated that for each unit increase (1 μg/m^3) in PM_{10} exposure, the growth in FEV_1 from 5 to 11 years was 23 mL smaller; and for each unit increase (1 μg/m^3) of NO_2 exposure, the growth in FEV_1 was 14 mL smaller [$\Delta FEV_1 = \beta / 100 \times 1.65 \times 1{,}000$]. Results of cross-sectional analyses conducted at other time points are shown in Supplemental Material, Table S3; we observed no statistically significant association between PM_{10} or NO_2 exposure windows and FEV_1 in cross-sectional analyses.

Association between exposure to pollutants and postbronchodilator FEV_1. At 11 years of age, there was no association between PM_{10} or NO_2 exposure (MEEM) during the summer or winter and postbronchodilator FEV_1 percent predicted (Table 3). However, there was a significant negative association between postbronchodilator FEV_1 and the annual average NO_2 exposure from 10 to 11 years of age estimated by the lifetime model (β = –1.00; 95% CI: –1.96, –0.03, *p* = 0.043). In the longitudinal models, we observed a significant negative association between postbronchodilator FEV_1 and PM_{10} and NO_2 exposure over time [PM_{10}: β = –3.59 (95% CI: –5.36, –1.83); NO_2: β = –1.20 (95% CI: –1.97, –0.43)]. Based on the average predicted FEV_1 of 1.65 L, these would be equivalent to a growth deficit in post bronchodilator FEV_1 of 59 mL from 5 to 11 years of age per unit increase in PM_{10}, and a growth deficit of 20 mL from 5 to 11 years per unit increase in NO_2. For completeness results of cross-sectional analyses conducted at other time points are shown in Supplemental Material, Table S4. Table S4 shows significant negative associations between postbronchodilator FEV_1 and early-life PM_{10} ($\beta_{\text{Age 0–1}} = –3.00$; 95% CI: –5.29, –0.71; $\beta_{\text{Age 0–5}} = –4.70$; 95% CI: –7.85, –1.55) and NO_2 exposures ($\beta_{\text{Age 0–1}} = –0.91$; 95% CI: –1.77, –0.05).

Discussion

To our knowledge, this is the first study to estimate the effect of modeled individual lifetime exposure to PM_{10} and NO_2, from birth through elementary school, on the development of lung function measured throughout childhood. With both exposure and lung function modeled longitudinally, our results indicated a small but statistically significant impairment in growth of FEV_1 with an increase in exposure to air pollutants. We estimated the size of this effect to be a loss of 23 mL in the growth in FEV_1 from 5 to 11 years of age per unit increase in PM_{10} (~ 3.8 mL/year), and 14 mL per unit increase of NO_2 exposure (~ 2.3 mL/year). In addition, we observed significant associations of PM_{10} and NO_2 exposures with postbronchodilator FEV_1. In cross-sectional analyses, using a detailed assessment of summer and winter pollutant exposure at 11 years, we found no associations between air pollution and contemporaneous measures of lung function.

One of the strengths of this study was the use of the comprehensive validated MEEM model to estimate exposures for cross-sectional analyses of outcomes at 11 years of age. This model provided weighted estimates of exposure based on time–activity patterns and NO_2 and PM_{10} models with a high spatiotemporal resolution. Ideally, we would have used MEEM to estimate lifetime exposure of each child. However, MEEM requires detailed descriptions of the house design that were not available longitudinally for the approximately 50% of children who had moved house from their original home during follow-up. Therefore we used the lifetime model—a slightly simplified version of MEEM that did not require detailed knowledge of the home environment to estimate exposures on a monthly basis from birth to 11 years for longitudinal analyses. The ranges of exposures estimated by MEEM (9.7–28.0 μg/m^3 and 6.5–38.1 μg/m^3 for PM_{10} during the previous summer and winter, respectively; and 9.5–43.0 μg/m^3 and 10.3–47.2 μg/m^3 for NO_2, respectively) were greater than the corresponding estimates from the lifetime model at 10–11 years (PM_{10}: 8.8–14.0 μg/m^3; NO_2: 10.8–23.7 μg/m^3). Differences between estimates from each model reflect the different time periods used for averaging (3-month averages during summer and winter for MEEM, 12-month averages at 10–11 years of age for the lifetime model) and the use of the INDAIR model to estimate indoor exposures for MEEM, which captures peaks in exposure due to gas cooking and cigarette smoking, as well as very low exposures due to low air exchange rates. However, the lifetime model also improves over previously used exposure assessment methods by providing retrospective

Table 2. Summary of lung function measures at each review (mean ± SD).

Lung function measure	Age 3	Age 5	Age 8	Age 11
sR_{aw} (kPa/sec)[a]	1.10 (1.23)	1.17 (1.21)	1.22 (1.23)	1.26 (1.29)
FEV_1 (L)		1.05 ± 0.16	1.59 ± 0.25	2.30 ± 0.40
Predicted FEV_1 (L)		1.03 ± 0.27	1.60 ± 0.17	2.34 ± 0.29
FEV_1 (% predicted)		96.4 ± 12.7	99.0 ± 11.8	98.5 ± 11.7
FEV_1 postbronchodilator (% predicted)		104.9 ± 11.3		103.8 ± 11.5

[a] Geometric mean (GSD).

Table 3. Results of longitudinal analyses (GEE) of longitudinal PM_{10} and NO_2 exposure (based on the lifetime model) and lung function and cross-sectional analyses (multivariable linear regression) of PM_{10} and NO_2 exposure at 10–11 years of age (based on the lifetime model or MEEM) and lung function at 11 years of age.

Exposure metric/ lung function metric	Longitudinal exposure and lung function			Exposure at age 10–11 (lifetime model) and lung function at age 11			Winter exposure before age 11 review (MEEM) and lung function at age 11			Summer exposure before age 11 review (MEEM) and lung function at age 11		
	β[a] (95% CI)	*p*-Value	*n*[b]	β[a] (95% CI)	*p*-Value	*n*[b]	β[a] (95% CI)	*p*-Value	*n*[b]	β[a] (95% CI)	*p*-Value	*n*[b]
PM_{10} (μg/m^3)												
Ln sR_{aw} (kPa/sec)[c]	0.009 (–0.027, 0.010)	0.37	453	–0.007 (–0.054, 0.040)	0.77	352	–0.001 (–0.011, 0.008)	0.78	315	0.001 (–0.008, 0.009)	0.90	298
FEV_1 (% predicted)[d]	–1.37 (–2.52, –0.23)	0.019	342	–1.13 (–3.36, 1.09)	0.32	373	–0.20 (–0.65, 0.26)	0.39	334	0.07 (–0.33, 0.47)	0.73	317
FEV_1 after bronchodilator treatment (% predicted)[d]	–3.59 (–5.36, –1.83)	< 0.001	176	–1.71 (–3.94, 0.53)	0.13	366	–0.14 (–0.61, 0.34)	0.57	327	0.15 (–0.27, 0.57)	0.48	310
NO_2 (μg/m^3)												
Ln sR_{aw} (kPa/sec)[c]	–0.007 (–0.016, 0.003)	0.16	453	0.002 (–0.020, 0.023)	0.88	352	0.001 (–0.004, 0.007)	0.64	315	–0.001 (–0.006, 0.004)	0.57	298
FEV_1 (% predicted)[d]	–0.83 (–1.39, –0.28)	0.003	342	–0.83 (–1.79, 0.14)	0.093	373	–0.10 (–0.36, 0.17)	0.47	334	0.05 (–0.18, 0.29)	0.66	317
FEV_1 after bronchodilator treatment (% predicted)[d]	–1.20 (–1.97, –0.43)	0.002	176	–1.00 (–1.96, –0.03)	0.043	366	–0.01 (–0.29, 0.27)	0.93	327	0.08 (–0.17, 0.32)	0.53	310

GEE, generalized estimating equation.

[a] β coefficient per 1-μg/m^3 increase in exposure. [b] Number of children included in analysis. [c] Adjusted for age, sex, concurrent body mass index, concurrent atopy, concurrent asthma or wheeze, family history of asthma, hospitalization during first two years of life for lower respiratory tract infection, average 3-day background PM_{10} concentration prior to sR_{aw} measurement, mean Tanner stage. [d] Adjusted for age (only in GEE), concurrent atopy, concurrent asthma or wheeze, hospitalization during first two years of life for lower respiratory tract infection, gas cooker in home, mean Tanner stage.

estimates of monthly exposures that can be aggregated into different exposure time windows for longitudinal and cross-sectional analyses. Furthermore, using home and school address histories, we modeled exposure at an individual level, rather than a community level, thereby reducing the potential for exposure misclassification.

Because of the strong correlation between NO_2 and PM_{10} exposures in our study, we used single- rather than two-pollutant models. Many previous cohort studies of air pollution have included cigarette smoking and socioeconomic status as confounders in their analysis (Brunst et al. 2012; Li et al. 2000; Stocks and Dezateux 2003). Although it is likely that parental smoking and socioeconomic status affect lung function in children, we did not include them in our final model because they were not significant predictors of the outcomes, and we therefore assumed that they did not confound associations with air pollution exposures in our study. However, we cannot rule out residual confounding by these or other exposures. In addition, we acknowledge that our estimates of PM_{10} exposures do not necessarily represent the size fraction of particulate matter that is most damaging and that further studies of associations with fine or ultrafine particles are needed to address this.

Another strength of this study was its setting in the context of a population-based birth cohort with repeated measurements of lung function—an objective outcome that is not affected by recall or reporting bias—at four ages. Assessment of sR_{aw} enabled measurement of lung function from a young age (3 years). Assessing bronchodilator responses is a common diagnostic tool to test for reversible airway obstruction that can also be used to estimate the maximum achievable expiratory volume of a child. The results of our longitudinal analyses suggest an average annual growth deficit of 9.8 mL/year and 3.3 mL/year in the maximum achievable expiratory volume with each unit increase in PM_{10} and NO_2 exposure.

A limitation of this study was the relatively small sample sizes for some of the analyses, mostly due to missing exposure data. Exposure data were missing for children who moved outside the Greater Manchester area and for children with incomplete information on home and school addresses. However, the loss in precision due to sample size limitations may be partly offset by the use of detailed individual-level estimates of longitudinal exposures.

Most published studies have investigated the association between pollutant exposure and FEV_1 cross-sectionally—at a single time point only. Some of these studies also reported that PM_{10} or NO_2 exposures were associated with decreases in mean FEV_1, but not at a statistically significant level (Avol et al. 2001; Dockery et al. 1989; Oftedal et al. 2008). However, other studies have reported significant negative associations between air pollution exposure and FEV_1 (Gauderman et al. 2000, 2004; Horak et al. 2002; Peters et al. 1999; Rojas-Martinez et al. 2007), but often only in subgroups of children [e.g., only in girls (Peters et al. 1999), only in one age group (Gauderman et al. 2004), or only during one season (Horak et al. 2002)].

Few studies have estimated the longitudinal effects of pollutants on the growth in lung function (Table 4). The Children's Health Study was set in 12 communities of Southern California (USA), with a broad range of pollutant exposures (Gauderman et al. 2000, 2004). After 4 years of follow-up from 10 years of age, increasing community exposure to PM_{10} was associated with a reduced adjusted mean FEV_1 growth rate, with those in the most polluted community having an estimated cumulative reduction in FEV_1 of 3.4% over 4 years compared with those in the least polluted communities (Gauderman et al. 2000). After 8 years of follow-up, this association with PM_{10} was no longer statistically significant, although a much higher proportion of the children who lived in high-PM_{10} communities had a $FEV_1 < 80\%$ predicted. By the time children were 18 years of age, the average FEV_1 in the community with the highest NO_2 exposure was about 100 mL lower than that seen in the community with the lowest exposure (Gauderman et al. 2004). In a population of 975 8-year-old Austrian children who were followed for 3 years, significant negative associations with lung function growth were reported for winter NO_2 and summer $PM_{10,}$ even though higher concentrations of PM_{10} were present during the winter (Horak et al. 2002). A 3-year study of 3,170 children living in Mexico City, which has comparatively high pollution levels, reported statistically significant negative associations of both PM_{10} and NO_2 with growth in FEV_1 (Rojas-Martinez et al. 2007). Specifically, the authors estimated that an interquartile range (IQR) increase in PM_{10} (36.4 μg/m^3) was associated with a mean annual deficit in FEV_1 of 29 mL in girls and 27 mL in boys. Similarly, they estimated that an IQR increase in NO_2 (12.0 ppb) was associated with a mean annual deficit of 32 mL in girls and 26 mL in boys. When estimates are scaled to the same exposure increment and time period (Table 4), it is apparent that past and present longitudinal studies have estimated a very broad range of effect sizes on lung function growth.

Having found a longitudinal association during childhood, we find it interesting to speculate at which time point exposure to pollutants may be most damaging to lung function. The cross-sectional analysis of the detailed NO_2 and PM_{10} exposure estimates derived from MEEM showed no association between exposure and lung function at 11 years of age. However, for post-bronchodilator FEV_1 the cross-sectional analyses indicate that early exposures are associated with poorer lung function (see Supplemental Material, Table S4), but this association was not as evident for FEV_1 percent predicted (see Supplemental Material, Table S3). Previous research has suggested that lung development during infancy is particularly susceptible to environmental toxins and that exposure can result in irreversible lung damage (Dietert et al. 2000; Plopper and Fanucchi 2000). In the Children's Health Study, no significant associations of pollutant exposures were reported for older children (recruited at 13 and 15 years of age) who were also followed longitudinally (Gauderman et al. 2000). However, most epidemiological studies on children's lung function have assessed only present air pollution exposure (Götschi et al. 2008), and very little work has been done on early-life exposure (Oftedal et al. 2008). The results of the present study support the hypothesis that early life exposures may affect lung development in later life.

We found evidence of an impairment in lung function growth at apparently lower exposure levels than those of previous longitudinal studies of air pollution exposure and

Table 4. Comparison of average deficit in lung growth with findings from previously published population-based studies.

			Range of exposures (μg/m^3)		Average deficit in lung growth (mL/year) associated with 1-μg/m^3 increase in exposure^a	
Reference, country	Exposure assigned at	Study duration	PM_{10}	NO_2	PM_{10}	NO_2
Gauderman et al. 2000, 2004, USA	Community level	Age 10–14	20–65	10–70	0.20	0.19
Horak et al. 2002, Austria	Community level	Age 8–11	9–31	2–35	8.4	9.5
Rojas-Martinez et al. 2007, Mexico	Community level	Age 8–11	53–96	54–74	0.80 (girls), 0.74 (boys)	1.4 (girls), 1.1 (boys)
Present study, United Kingdom	Individual level	Birth–age 11	10–16	15–28	3.8	2.3

^{a}Calculated based on published figures, assuming a linear relationship between exposure and lung function.

lung function in children (Avol et al. 2001; Gauderman et al. 2004; Rojas-Martinez et al. 2007). However, exposure estimates in previous studies are not directly comparable with exposure estimates used in our study, because they were based on levels measured at centrally located outdoor pollution monitors. In contrast, our estimates accounted for both indoor and outdoor exposures, because children living in urban areas in industrialized countries spend most of their time indoors (Infante-Rivard 1993). Our previous work on MEEM has shown that a model allowing for indoor and outdoor exposure provides a better estimate of personal exposure than methods based solely on outdoor air pollution, which tended to overestimate personal exposure (Mölter et al. 2012). Therefore, it is possible that exposure levels assigned to children in previous studies based on outdoor monitors overestimated their true personal exposures. Nonetheless, the maximum outdoor concentrations of 70–80 $\mu g/m^3$ NO_2 and 60–90 $\mu g/m^3$ PM_{10} found in previous studies in Mexico (Rojas-Martinez et al. 2007) and the United States (Avol et al. 2001; Gauderman et al. 2004) do exceed the current regulatory limits for annual mean concentrations in the United Kingdom (NO_2 = 40 $\mu g/m^3$; PM_{10} = 40 $\mu g/m^3$) and are higher than concentrations typically measured at urban background monitoring stations in Manchester (Mölter et al. 2010a, 2010b).

Conclusions

Our findings suggest that lifetime exposure to PM_{10} and NO_2 may be associated with reduced growth in FEV_1 in children. Although the observed reductions in FEV_1 growth were small, and therefore may have little impact on healthy individuals, they could have implications for individuals with chronic respiratory disease, particularly obstructive lung diseases, or in children who go on to smoke cigarettes. Future follow-up will provide further insight on whether reductions in FEV_1 growth associated with air pollution persist into adulthood or disappear during adolescence.

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Short-Term Effects of PM_{10} and NO_2 on Respiratory Health among Children with Asthma or Asthma-like Symptoms: A Systematic Review and Meta-Analysis

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OBJECTIVE: Our goal was to quantify the short-term effects of particulate matter with aerodynamic diameter ≤ 10 µm (PM_{10}) and nitrogen dioxide (NO_2) on respiratory health of asthmatic children from published panel studies, and to investigate the influence of study and population characteristics as effect modifiers.

DATA EXTRACTION: After a systematic literature review, we extracted quantitative estimates of the association of PM_{10} and/or NO_2 with respiratory symptoms and peak expiratory flow (PEF). Combined effect estimates for an increase of 10 µg/m^3 were calculated by random effects meta-analysis for all studies and for different strata defined by study characteristics. The effect of publication bias was investigated with Egger's and Begg's tests and "trim-and-fill" analyses.

DATA SYNTHESIS: We identified 36 studies; 14 were part of the European Pollution Effects on Asthmatic Children in Europe (PEACE) study. Adverse associations of PM_{10} with asthma symptoms were statistically significant [odds ratio (OR) = 1.028; 95% confidence interval (CI), 1.006–1.051]. There were also associations, although not statistically significant, of PM_{10} with cough (OR = 1.012; 95% CI, 0.997–1.026) and on PEF (decrease of –0.082 L/min; 95% CI, –0.214 to 0.050). NO_2 had statistically significant associations with asthma symptoms in the overall analysis considering all possible lags (OR = 1.031; 95% CI, 1.001–1.062), but not when we evaluated only the 0–1 lag. We found no publication bias, although it appeared when excluding the PEACE studies. When we applied the trim-and-fill method to the data set without the PEACE studies, the results were similar to the overall estimates from all studies. There was an indication for stronger PM_{10} associations for studies conducted in summer, outside of Europe, with longer lags, and in locations with higher NO_2 concentrations.

CONCLUSIONS: We found clear evidence of effects of PM_{10} on the occurrence of asthma symptom episodes, and to a lesser extent on cough and PEF. The results for NO_2 are more difficult to interpret because they depend on the lag times examined. There was an indication of effect modification by several study conditions.

KEY WORDS: air pollution, asthma, children, NO_2, PM, short-term effects. *Environ Health Perspect* 118:449–457 (2010). doi:10.1289/ehp.0900844 [Online 12 November 2009]

Particulate matter (PM) with an aerodynamic diameter ≤ 10 µm (PM_{10}) and nitrogen dioxide (NO_2) are important ambient air pollutants regulated by European and national legislations. Measurements of PM_{10} include PM of different aerodynamic diameter (coarse, fine, and ultrafine PM), and the size distribution is related to the emission source, with the coarse fraction mainly originating from soil and natural sources and fine and ultrafine PM mainly originating from combustion or being secondary aerosols from sources that can be far away (Williams 1999). Notwithstanding possible long-range transport, most of NO_2 in the ambient air arises from oxidization of emitted NO_x from combustion mainly from motor engines in urban areas (Williams 1999), and it is considered to be a good marker of traffic-related air pollution.

The health effects of PM_{10} and NO_2 have been extensively reviewed, and air quality standards and guidelines have been proposed to protect public health [U.S. Environmental Protection Agency (EPA) 2005, 2008a; World Health Organization (WHO) Regional Office for Europe 2000, 2006]. Nevertheless, important clinical effects are currently detectable in real-life exposure to traffic-related pollutants among susceptible subgroups of the population, such as individuals with asthma. A recent study from London has clearly shown that asthmatic adults have a significant decrease in lung function after 2 hr of walking along a street in the center of London as opposed to walking in a nearby park (McCreanor et al. 2007). The effects were stronger in individuals with moderate asthma compared with individuals with mild asthma. Several studies have been conducted among children with asthma focusing on the short-term effects of air pollution, that is, its effects on daily symptoms and lung function. Most studies used air pollution measurements from central monitoring sites that provide daily data. Mostly PM_{10}, NO_2, and ozone (O_3) have been evaluated; results for carbon monoxide, black smoke, and $PM_{2.5}$ (PM with aerodynamic diamter ≤ 2.5 µm) have been less reported to date. Studies on long-term effects typically involve proximity of the residence to roads, but they do not provide information on short temporal scales.

Both PM_{10} and NO_2 have been associated with increases in the frequency of asthma symptoms and with lung function decrements in children on a day-to-day scale (Gielen et al. 1997; Ostro et al. 2001; Pope and Dockery 1992; Roemer et al. 1993; Romieu et al. 1996; Schildcrout et al. 2006; van der Zee et al. 1999; Vedal et al. 1998). However, the results of the existing studies have not been consistent, and a comprehensive quantitative evaluation of the respiratory effect in children is still lacking.

Two meta-analyses on the short-term effects of PM_{10} on children's respiratory health have previously been performed (Anderson et al. 2004; Ward and Ayres 2004). Anderson et al. (2004) reviewed the effects on cough and medication use in European panel studies, a large number of which were conducted within the multicenter PEACE (Pollution Effects on Asthmatic Children in Europe) study that provided 28 of the 34 effect estimates. In their review, they found no effect of PM_{10} on cough in children [odds ratio (OR) = 0.999 for 10-µg/m^3 increase in PM_{10}; 95% confidence interval (CI), 0.987–1.011]. Ward and Ayres (2004) performed a meta-analysis of worldwide panel studies published through 2002 that included asthmatic and healthy children. They found a significant effect of PM_{10} on cough (OR = 1.004 per unit µg/m^3 increase PM_{10}; 95% CI, 1.002–1.006), on lower respiratory symptoms (LRS) or wheeze (OR = 1.004 per 1 µg/m^3 PM_{10}; 95% CI, 1.002–1.005), and on peak expiratory flow (PEF) (a decrease of –0.033 L/min per 1 µg/m^3 in PM_{10}; 95% CI, –0.019 to –0.047). In both meta-analyses, the results of the large multicenter European PEACE study had a strong influence because of its primarily null results.

To our knowledge, no quantitative meta-analysis on the effects of NO_2 among children with asthma has so far been performed. The available evidence is inconsistent, with some studies showing a detrimental effect

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of NO_2 on symptoms or lung function and other investigations indicating no effect (Ackermann-Liebrich and Rapp 1999).

To provide a quantitative estimate of the acute effects of short-term exposure to PM_{10} and NO_2 on respiratory symptoms and lung function in asthmatic children, we performed a meta-analysis on panel studies published through July 2008. We assessed the role of the PEACE study on the overall evaluation, and we paid specific attention to the influence of publication bias. Because study characteristics and pollution mixtures vary with space and time, some heterogeneity among the study results conducted at different locations is to be expected. We therefore investigated the influence of study and population characteristics on the outcomes.

Methods

We conducted a systematic search of the literature from 1990 through July 2008 that focused on the short-term effects of outdoor NO_2 and PM_{10} on respiratory health outcomes as determined in panel studies. To focus our study, we did not consider exposure to O_3 or studies on indoor exposure; the latter has been typically investigated for long-term effects. We investigated lung function as measured by PEF and symptoms of cough and asthma, the latter being reported as wheeze or LRS. A MEDLINE (National Library of Medicine 2008) search was carried out; the search strings consisted of "asthma OR wheeze OR cough OR bronchitis OR lung function," "air AND pollut*," and "PM_{10} OR PM(10)" and "NO2 OR "NO(2)" OR "nitrogen dioxide." Limits were set to retrieve only children ("All Child 0–18 years"). The exact search history is available from the authors. These criteria were applied to maximize sensitivity and to not miss any relevant publication. The age range of children in the panel studies was 5–19 years. Wheezing among infants was not considered because the asthma phenotype differs in very young children and there are essentially no panel studies on infants.

The references were then selected by hand according to the following inclusion/exclusion criteria: exclusion of indoor and laboratory studies; inclusion of panel studies on asthmatic or symptomatic (see definition below) children that reported a quantitative effect (regression coefficients); inclusion of only one publication of the same study/database for each outcome. With regard to the statistical analysis, we included only studies that controlled for the effect of daily temperature and day of the week, because these are important confounders and should be adjusted for to detect short-term effects of air pollution.

For the definition of "asthmatics" or "symptomatic" children, we relied on the criteria reported in the individual publications. Generally, children with asthma confirmed by a physician or who were referred from clinics, school nurses, and so on, with an asthma diagnosis were classified as "asthmatics." We considered "symptomatic" children who reported, mostly in a questionnaire, wheezing or cough apart from cold or an asthma diagnosis, or who took medication for asthma.

The evaluated outcomes were "asthma symptoms" and "cough," and the definitions differed in various studies, as indicated in "Results." For PEF, we included only studies that reported changes as liters per minute or that allowed us to calculate the changes in liters per minute from the given percentages and were therefore directly comparable. Other lung function parameters and exhaled nitrogen oxide were not considered, because these studies are relatively scarce.

For the meta-analysis, we used the coefficients derived from single-pollutant models. Where necessary, the coefficient estimates were recalculated to reflect a 10-$\mu g/m^3$ increase in pollutant assuming a linear relationship over the considered range. When coefficients for different lag times were given, we used the one that resulted in a statistically significant effect or, when all estimates were either significant or not significant, the lag reflecting the highest effect size. The same criterion was applied if lung function measurements were performed in the morning and in the evening. These criteria were modified in a sensitivity analysis as indicated below.

Combined estimates of the natural logarithm of the OR for respiratory symptoms and the linear regression coefficients for PEF, respectively, were calculated for all studies with a fixed effects and a random effects meta-analysis model (DerSimonian and Laird 1986; Petitti 2001) using the meta command of STATA (releases 8 and 9.1; StataCorp., College Station, TX, USA). This command uses inverse-variance weighting to calculate combined estimates. Although a fixed-effects model assumes that the studies reflect the same underlying average effect, in a random-effects model the study effects are coming from a common underlying distribution of effects. The corresponding weights include an additional term that reflects the between-study heterogeneity due to unexplained sources. Heterogeneity was assessed by calculating the I^2 of Higgins and Thompson, which reflects the proportion of total variation in the combined estimate that is due to heterogeneity between studies (Higgins and Thompson 2002).

We evaluated publication bias with both the Begg test and the Egger test (Begg and Mazumdar 1994; Egger et al. 1997). The Egger et al. regression asymmetry test tends to suggest the presence of publication bias more frequently than the Begg adjusted rank correlation test, which has a low power.

Where necessary, a trim-and-fill analysis was performed to take account of publication bias (Duval 2000). This procedure estimates the number and outcomes of theoretical missing studies and incorporates them into the meta-analysis. All the calculations were done using the metabias and metatrim commands in STATA.

To explore heterogeneity in meta-analysis estimates, we considered the influence of the following study characteristics on meta-analytical estimates: continent (Europe; other countries), season (summer only; any other cases), population [asthmatics (confirmed diagnosis); symptomatics], duration (≤ 2 or > 2 months), lag (≤ 2 or > 2 days), average PM_{10} levels (< 40 or ≥ 40 $\mu g/m^3$), and average NO_2 levels (< 40 or ≥ 40 $\mu g/m^3$). The influence of study characteristics was investigated by calculating the combined effect for each stratum and evaluating the difference between strata-specific estimates. The null hypothesis that the difference between the estimates from the two strata equals 0 was tested (with Z-score), and the corresponding p-value is reported here. Statistical significance was defined as $p < 0.05$ for all analyses.

Because the choice of the lag was a critical step, we performed additional analyses using, for all the studies, the effect estimate at lag 0–1 (instead of the most significant lag). The following criteria were applied. The default was lag 1; if lag 1 was not available, lag 0 or lag 0–1 was considered instead. In addition, we calculated the combined effects for PEF using only the evening values.

Results

We retrieved a total of 77 references for PM_{10} and 324 for NO_2. Applying the inclusion/exclusion criteria outlined in "Materials and Methods," 36 studies on PM_{10} and 24 on NO_2 remained to be included in the meta-analysis (Table 1). Some of the excluded studies were on indoor NO_2, notably related with cooking and heating. Other studies were time-series analyses on hospital admissions, and a few studies were on pathologic mechanisms and exposure assessment. Of the total of 36 studies (on 51 populations), 14 were PEACE studies (28 populations). In this review, we refer to each population as a separate study and use the corresponding estimates. Peacock et al. (2003) studied a subgroup of wheezy children but did not give estimates for the coefficient for this group. Nevertheless, because the authors stated that there was no effect modification by wheeze, we took the estimate for all children instead.

Of the total of 51 populations studied, 36 were from Europe and 15 from elsewhere, mainly the United States. Thirty populations were from urban areas, and 20 studies were conducted in rural environments (one unspecified). Four studies were carried out in the summer only; the other studies were conducted mainly in winter or during most of the year. The mean 24-hr average for NO_2 ranged from 8 to 77 μg/m^3, and the mean 24-hr average for PM_{10} ranged from 11 to 167 μg/m^3 (but only Mexico City had a value of 167 μg/m^3; all the others had a value < 100 μg/m^3).

The definition of the outcome regarding asthma symptoms varied among the studies: We included the estimates for wheeze from five studies (Jalaludin et al. 2004; Roemer et al. 1993; Romieu et al. 1996, 1997; Vedal et al. 1998); 35 studies used a variable "lower respiratory symptoms" or "asthma symptoms," which in most studies (including PEACE studies) consisted of wheezing, shortness of breath, and asthma attacks (Gielen et al. 1997; Ostro et al. 2001; Pope and Dockery 1992; Roemer et al. 1998b; van der Zee et al. 1999). Other studies also included chest tightness (Delfino et al. 1998, 2002, 2003; Mortimer et al. 2002; Yu et al. 2000), sputum production (Delfino et al. 2002, 2003), or cough (Delfino et al. 1998, 2002, 2003; Mortimer et al. 2002; Ostro et al. 2001; Pope and Dockery 1992;

Table 1. Study characteristics of the panel studies.

Study	Outcomes studied[a]	Pollutant studied	Year of study	Continent	Urban/ rural	*n* (duration in days)	Season	Population	Pollutant 24-hr mean (μg/m^3)[b]	
									PM_{10}	NO_2
Pope and Dockery 1992	LRS, cough, PEF	PM_{10}	1990	Other	Rural	39 (70)	Other	Symptomatics	56	—
Roemer et al. 1993	LRS, cough, PEF	PM_{10}	1990	Europe	Rural	73 (90)	Other	Symptomatics	76	71[c]
Romieu et al. 1996	LRS, cough, PEF	PM_{10}	1991	Other	Urban	71 (60)	Other	Asthmatics	167	75
Gielen et al. 1997	LRS, cough	PM_{10}	1995	Europe	Urban	61 (60)	Summer only	Asthmatics	31	—
Peters et al. 1997	Cough, PEF	PM_{10}	1991	Europe	Urban	89 (210)	Other	Asthmatics	55	—
Romieu et al. 1997	LRS, cough, PEF	PM_{10}	1991	Other	Urban	67 (60)	Other	Asthmatics	54	37–169[d]
Delfino et al. 1998	LRS	PM_{10}	1995	Other	Rural	24 (90)	Summer only	Asthmatics	43	—
Segala et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1992	Europe	Urban	41 (175)	Other	Asthmatics	34	57
Vedal et al. 1998	Cough, PEF	PM_{10}	1990	Other	Rural	75 (492)	Other	Asthmatics	27	—
Tiittanen et al. 1999	Cough, PEF	PM_{10}	1995	Europe	Urban	49 (42)	Other	Symptomatics	50%ile, 28	50%ile, 15
van der Zee et al. 1999	LRS, cough	PM_{10}, NO_2	1993	Europe	Urban	142 (90)	Other	Symptomatics	38	49
van der Zee et al. 1999	LRS, cough	PM_{10}, NO_2	1993	Europe	Rural	178 (90)	Other	Symptomatics	31	27
Jalaludin et al. 2000	PEF	PM_{10}, NO_2	1994	Other	Urban	125 (300)	Other	Asthmatics	23	28
Yu et al. 2000	LRS	PM_{10}	1993	Other	Urban	133 (58)	Other	Asthmatics	10	—
Ostro et al. 2001	LRS, cough	PM_{10}, NO_2	1993	Other	Urban	138 (90)	Summer only	Asthmatics	51	77[c]
Delfino et al. 2002	LRS	PM_{10}, NO_2	1996	Other	Rural	22 (61)	Other	Asthmatics	20	26[c]
Just et al. 2002	LRS, cough	PM_{10}, NO_2	1996	Europe	Urban	82 (90)	Other	Asthmatics	24	54
Mortimer et al. 2002	LRS	PM_{10}, NO_2	1993	Other	Urban	846 (14)	Summer only	Asthmatics	—	61
Aekplakorn et al. 2003	PEF	PM_{10}	1997	Other	Rural	88 (53–61)	Other	Asthmatics	50%ile, 22–25[e]	No NO_2 measured
Delfino et al. 2003	LRS, PEF	PM_{10}, NO_2	1999	Other	Urban	22 (90)	Other	Asthmatics	60	8[c]
Peacock et al. 2003	PEF	PM_{10}, NO_2	1996	Europe	—	179 (63)	Other	Symptomatics	18–23[e]	31–36[e]
Jalaludin et al. 2004	LRS, cough	PM_{10}, NO_2	1994	Other	Urban	148 (> 30)	Other	Symptomatics	23 (0600–2100 hr)	28 (0600–2100 hr)
Schildcrout et al. 2006	LRS	PM_{10}, NO_2	1993	Other	Urban	990 (60)	Other	Asthmatics	50%ile, 18–34[e]	50%ile, 34–59[e]
PEACE studies										
Baldini et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	68 (65)	Other	Symptomatics	62	68
Baldini et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	60 (65)	Other	Symptomatics	70	33
Beyer et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	75 (172)	Other	Symptomatics	40	27
Beyer et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	63 (172)	Other	Symptomatics	33	26
Clench-Aas et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	56 (70)	Other	Symptomatics	19	49
Clench-Aas et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	68 (70)	Other	Symptomatics	11	21
Englert et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	50 (58)	Other	Symptomatics	52	38
Englert et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	66 (58)	Other	Symptomatics	43	21
Forsberg et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	75 (84)	Other	Symptomatics	13	25
Forsberg et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	72 (84)	Other	Symptomatics	12	15
Haluszka et al. 1998	LRS, cough, PEF	PM_{10}	1993	Europe	Urban	73 (82)	Other	Symptomatics	60	—
Haluszka et al. 1998	LRS, cough, PEF	PM_{10}	1993	Europe	Rural	76 (76)	Other	Symptomatics	56	—
Kalandidi et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	87 (60)	Other	Symptomatics	99	75
Kalandidi et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	80 (60)	Other	Symptomatics	50	20
Kotesovec et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	91 (60)	Other	Symptomatics	74	49
Kotesovec et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	77 (60)	Other	Symptomatics	32	13
Nielsen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	78 (60)	Other	Symptomatics	23	21
Nielsen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	82 (60)	Other	Symptomatics	16	9
Niepsuj et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	72 (83)	Other	Symptomatics	69	69
Niepsuj et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	73 (83)	Other	Symptomatics	74	70
Rudnai et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	76 (61)	Other	Symptomatics	61	35
Rudnai et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	63 (67)	Other	Symptomatics	52	25
Timonen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	85 (72)	Other	Symptomatics	18	28
Timonen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	84 (72)	Other	Symptomatics	13	14
Vondra et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	66 (85)	Other	Symptomatics	53	45
Vondra et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	68 (85)	Other	Symptomatics	50	13
van der Zee et al. 1998	PEF	PM_{10}, NO_2	1993	Europe	Urban	55 (101)	Other	Symptomatics	45	46
van der Zee et al. 1998	PEF	PM_{10}, NO_2	1993	Europe	Rural	71 (93)	Other	Symptomatics	44	27

[a] LRS is equivalent to asthma symptoms. [b] Mean of the 24-hr means unless otherwise indicated. [c] Extrapolated from 1-hr maximum. [d] Range of means over the study period. [e] Means from more than one location.

Yu et al. 2000). In the latter studies, no separate effect estimate for cough was given except by Pope and Dockery (1992). Cough was not more precisely defined except for nocturnal cough (Just et al. 2002), cough during the day or the previous night (Peters et al. 1997), and wet and dry cough (Pope and Dockery 1992).

The effect estimates extracted from the individual studies are given in the Supplemental Material, Table 1 (doi:10.1289/ehp.0900844) and are illustrated in Figures 1–3, which also give the combined effects calculated in the meta-analysis. When we considered all the studies in the fixed-effects models, we found a significant increase of 2.3% in asthma symptoms, 1.4% for cough, and –0.117 min/L for PEF for a 10-μg/m^3 increase in PM_{10} (Table 2). However, we observed a considerable degree of heterogeneity among the studies, with I^2 ranging from 35% to 77%. Therefore, the estimates based on the random effects model are likely to represent the overall effect more accurately. For an increase of 10 μg/m^3 of PM_{10}, we found a significant increase of 2.8% in asthma symptoms, and an increase for cough (1.2%) and a decrease of PEF (–0.082 L/min) that were borderline significant. For an increase of 10 μg/m^3 NO_2, we found a significant increase in asthma symptoms of 3.1%. We found no clear association of NO_2 with cough or PEF; only when we excluded the PEACE studies did we find evidence of effect for NO_2 on cough.

When we considered all the studies, we found no evidence of publication bias. When we excluded the PEACE studies, publication bias was present for asthma symptoms for PM_{10} and NO_2; after applying the trim-and-fill procedure, the random-effects estimates decreased from 5.5% to 3.5% and from 3.9 to 3.2, respectively, and were therefore similar to the estimates for all studies. We also saw a tendency for a similar publication bias for cough (PM_{10} and NO_2), with significant values for the Egger test but not for the Begg test. However, the resulting trim-and-fill estimates for cough were more similar to those of the non-PEACE studies than to that for all studies (Table 2).

We found an effect modification of the effect of PM_{10} on asthma symptoms by continent (stronger association outside Europe), season (stronger association in studies carried out in summer only), study population (stronger effect among asthmatic children), and PM_{10} level (stronger association at levels < 40 μg/m^3) (Table 3). When we excluded the PEACE studies, only season remained near significance (p < 0.1). For the effect of PM_{10} on cough (Table 4), there were higher associations in studies conducted outside of Europe, with lag > 2 days, or with higher NO_2 levels; these effect modifications remained when excluding the PEACE studies. For the effect of PM_{10} on PEF (Table 4), there was a tendency for a higher decrease in PEF in asthmatic than in symptomatic children. We found no consistent effect modification, and there was no evidence for effect modification of the association between NO_2 and any of the investigated outcomes s (Table 3 for asthma; for cough and PEF, data not shown).

The results of the sensitivity analyses based on the predefined lag 0–1 (i.e., lag 1 or 0 or 0–1) and on evening PEF showed mostly a similar pattern, especially for PM_{10}, although the associations were generally weaker [see Supplemental Material, Table 3 (doi:10.1289/ehp.0900844)]. However, the associations of NO_2 with asthma symptoms and cough were not significant in this analysis. We found effect modification even when we omitted the PEACE studies (see Supplemental Material, Tables 4 and 5), for the effect of NO_2 on asthma symptoms, with higher associations for asthmatics

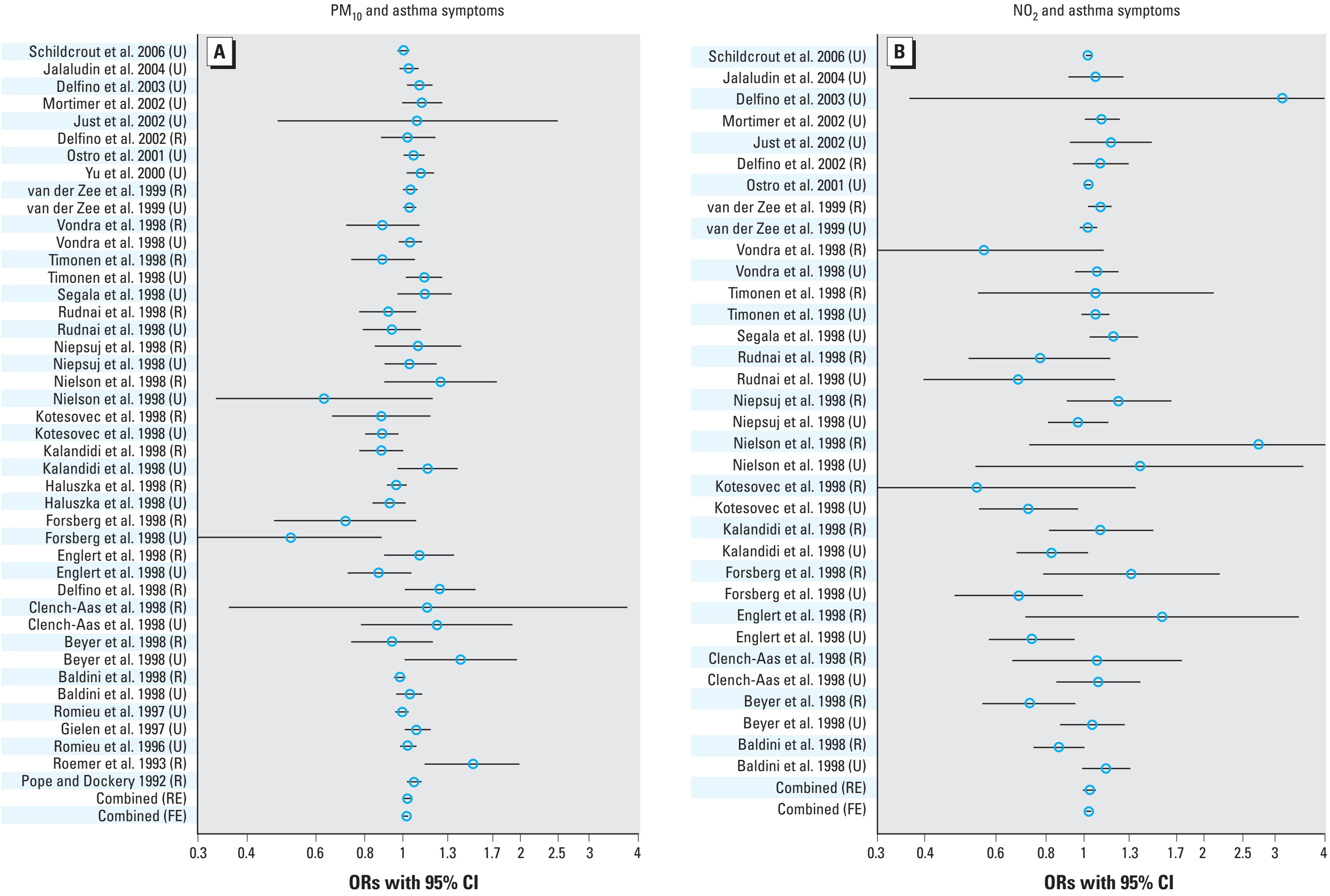

Figure 1. ORs with 95% CIs for the association between a rise of 10 μg/m^3 PM_{10} (*A*) or NO_2 (*B*) and the occurrence of asthma symptoms. Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

and during the summer (the latter based on two studies in one stratum). Furthermore, the estimated effects of PM_{10} on asthma symptoms were higher at higher concentrations of NO_2.

Discussion

Our meta-analysis shows effects of PM_{10} on both asthma symptoms and cough. We found no indication of publication bias when we considered all the evidence. For NO_2, we found statistically significant associations with asthma symptoms in the overall analysis but not in the sensitivity analysis restricted to the 0–1 lags. The effects of air pollutants on PEF were limited to PM_{10}, and we saw a stronger association when we excluded the PEACE studies from the analysis. We found an indication of effect modification of PM_{10}, with higher associations with asthma symptoms during summer and with cough for studies conducted outside of Europe, for a lag > 2 days, and at higher ambient NO_2 concentrations. When considering lags 0–1 only, the pattern of effect modification was different.

A previous meta-analysis considered panel studies in children and summarized the evidence for PM_{10} up through June 2002 (Ward and Ayres 2004). Our meta-analysis extends this work further up through July 2008, adding 11 studies. On the other hand, we did not include nine studies (two from Europe) included in the Ward and Ayres (2004) analysis because the panels evaluated asymptomatic children and we focused specifically on children with asthma. Our estimates of the PM_{10} effect on asthma symptoms and cough are similar to those of the previous meta-analysis [1.04 and 1.028 for asthma symptoms, 1.04 and 1.031 for cough in Ward and Ayres (2004) and in our analysis, respectively]. Our random effects estimate for PEF is weaker than that from Ward and Ayres (–0.082 vs. –0.33 L/min for a 10-$\mu g/m^3$ increase), whereas the fixed effects estimates are similar (–0.117 vs. –0.12 L/min).

We found no publication bias when considering all studies. However, excluding the PEACE studies, which highly influenced the estimates from the meta-analyses, resulted in clear publication bias for asthma symptoms, but less so for cough. The PEACE studies reported, on average, no effects of air pollution, with very few individual centers showing an association with PM_{10} (Roemer et al. 1998a). It is, on the one hand, the only multicenter series of studies that has been conducted with a unified protocol and whose results are not biased by publication procedures. On the other hand, limitations of the PEACE study have to be considered (Roemer et al. 1998a, 2000). There is concern that the entire study series might have been influenced by an influenza epidemic during the study period. If the study period is relatively short (e.g., 2 months as in the PEACE study), such unexpected events might confound the results, and it is generally more difficult to adjust adequately for time trend. In our analyses, we found no significant difference between studies with durations longer or shorter than 2 months. Nevertheless, for asthma symptoms, the estimate from the studies with durations longer than 2 months was slightly higher and statistically significant. In the Netherlands, where the data was collected during three winters instead of just one, there were clear effects of air pollution in symptomatic children (Roemer et al. 2000; van der Zee et al. 1999). In addition, all PEACE studies were carried out in the winter, when the effect of respiratory infections will putatively be greater compared with summer. Furthermore, in our analysis, we have found statistically greater associations in summer for asthma symptoms.

To the best of our knowledge, this is the first meta-analysis for effects related to

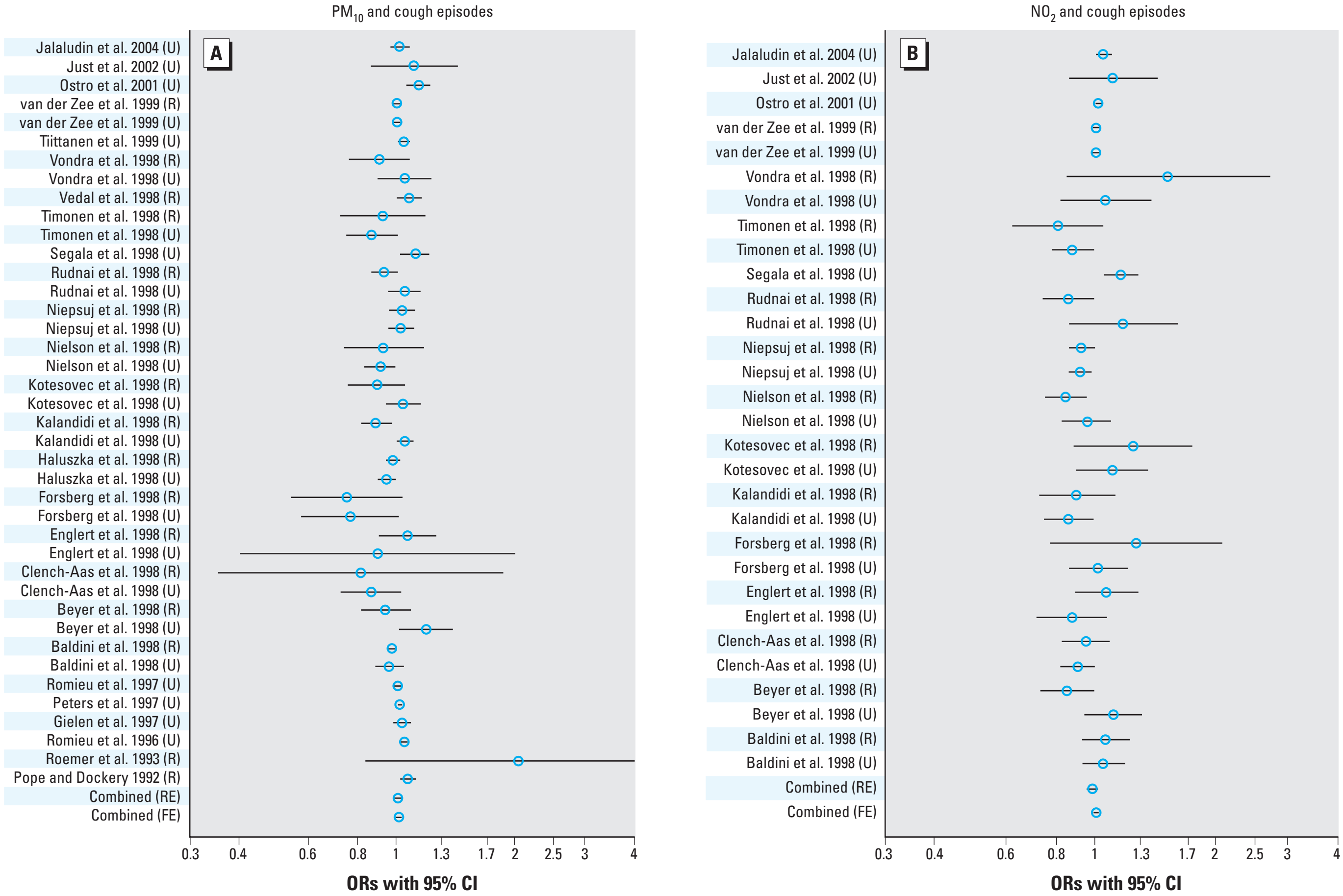

Figure 2. ORs with 95% CIs for the association between a rise of 10 $\mu g/m^3$ PM_{10} (*A*) or NO_2 (*B*) and the occurrence of cough episodes. Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

monitored outdoor NO_2 on respiratory health in asthmatic children, although the main investigations on NO_2 have been extensively reviewed (U.S. EPA 2008b; WHO Regional Office for Europe 2006). *In vitro* studies at comparatively low concentrations of NO_2, but still notably higher than ambient levels (400 ppb or 760 μg/m^3), have shown cell damage accompanied by release of cytokines, such as tumor necrosis factor-α and interleukin-8 (Devalia et al. 1993). In controlled human studies, the same concentration for 1 hr led to an increased early and late asthmatic response (measured by forced expiratory volume in 1 sec) after challenge with house dust mite allergen compared with ordinary air (Tunnicliffe et al. 1994). Similarly, a 30-min exposure to 500 μg/m^3 NO_2 increased the early-phase response to an otherwise nonsymptomatic allergen dose (Strand et al. 1998). Although such concentrations can be reached during some episodes, the usual ambient concentrations of NO_2 are lower. On the other hand, several studies on hospital admissions and emergency department visits for asthma conducted in Europe and elsewhere [reviewed by U.S. EPA (2008b); WHO Regional Office for Europe (2006)] did find an independent effect of NO_2. Therefore, the extent to which the observed associations are related to a direct effect of NO_2 and/or reflect the fact that NO_2 is a marker for the urban pollution mix, particularly for ultrafine

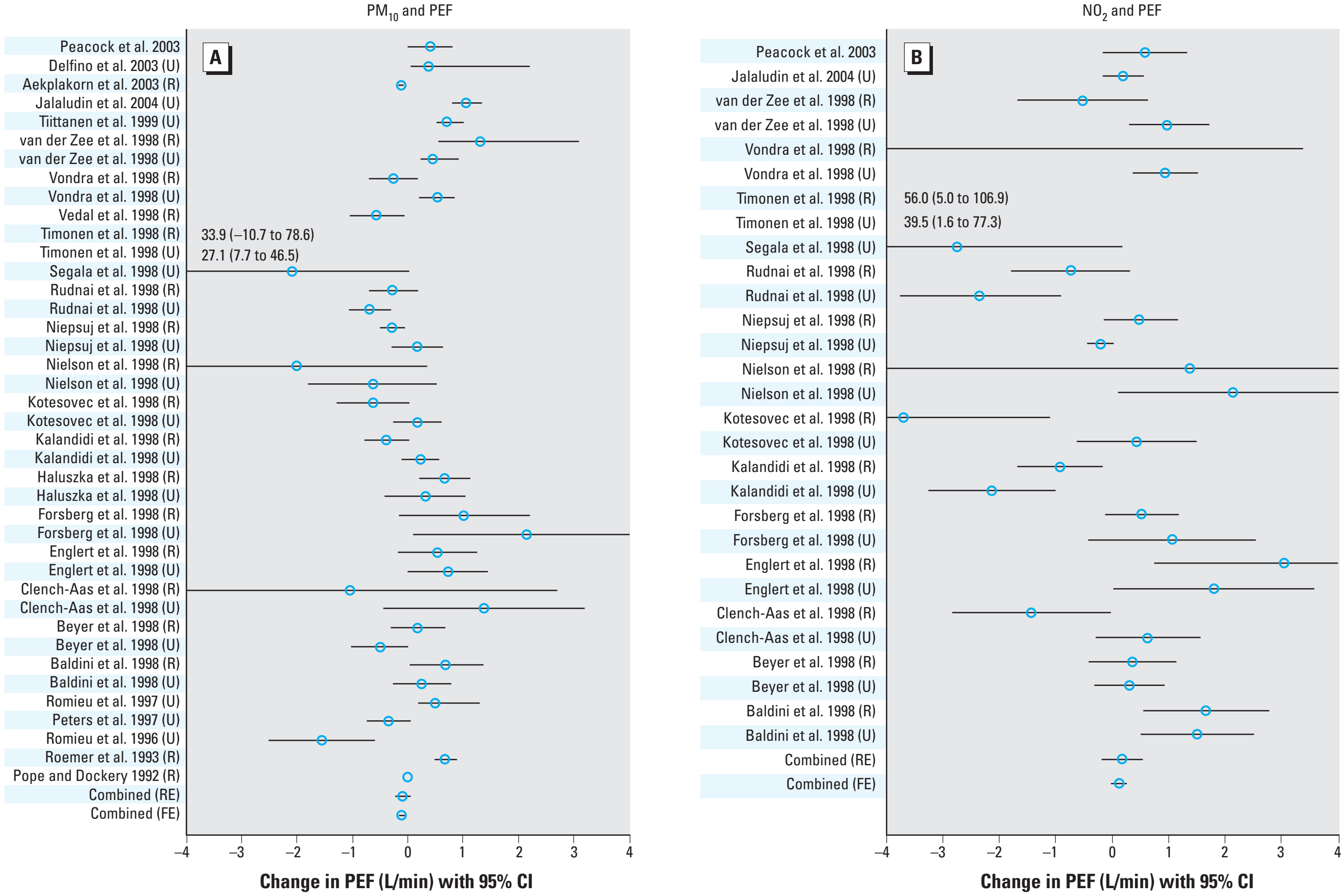

Figure 3. Mean increase in PEF (L/min) with 95% CIs for a rise of 10 μg/m^3 PM_{10} (*A*) or NO_2 (*B*). Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

Table 2. Association of PM_{10} and NO_2 exposure with episodes of asthma symptoms, episodes of cough, and PEF in children symptomatic for or diagnosed with asthma.

	PM_{10}					NO_2				
Symptom	*n*	OR_F/β_F (95% CI)	OR_R/β_R (95% CI)	*p*-Value(I^2)	*p*-Value[a]	*n*	OR_F/β_F (95% CI)	OR_R/β_R (95% CI)	*p*-Value(I^2)	*p*-Value[a]
Asthma symptoms										
All studies	43	1.023 (1.013 to 1.034)	1.028 (1.006 to 1.051)	< 0.001 (59%)	0.779 (0.675)	34	1.026 (1.016 to 1.037)	1.031 (1.001 to 1.062)	< 0.001 (50%)	0.746 (0.594)
Without PEACE studies	17	1.035 (1.023 to 1.047)	1.055 (1.032 to 1.078)	0.002 (56%)	0.000 (0.053)	10	1.028 (1.017 to 1.039)	1.039 (1.018 to 1.061)	0.125 (35%)	0.001 (0.152)
Trim-and-fill estimate	24	1.028 (1.016 to 1.039)	1.035 (1.012 to 1.058)	< 0.0001 (61%)		15	1.026 (1.015 to 1.037)	1.032 (1.008 to 1.057)	0.052 (41%)	
Cough										
All studies	40	1.014 (1.008 to 1.019)	1.012 (0.997 to 1.026)	< 0.001 (69%)	0.442 (0.316)	30	1.006 (0.995 to 1.016)	0.987 (0.960 to 1.014)	< 0.001 (65%)	0.394 (0.158)
Without PEACE studies	14	1.020 (1.014 to 1.026)	1.035 (1.020 to 1.050)	< 0.001 (72%)	0.002 (0.07)	6	1.018 (1.006 to 1.030)	1.031 (1.005 to 1.057)	0.006 (69%)	0.007 (0.085)
Trim-and-fill estimate	19	1.018 (1.012 to 1.024)	1.027 (1.011 to 1.043)	< 0.001 (72%)		8	1.015 (1.003 to 1.026)	1.018 (0.988 to 1.050)	< 0.001 (76%)	
PEF[b]										
All studies	40	–0.117 (–0.160 to –0.073)	–0.082 (–0.214 to 0.050)	< 0.001 (72%)	0.456 (0.428)	29	0.130 (–0.008 to 0.268)	0.180 (–0.184 to 0.544)	< 0.001 (77%)	0.433 (0.925)
Without PEACE studies	12	–0.145 (–0.195 to –0.096)	–0.272 (–0.449 to –0.095)	< 0.001 (69%)	0.061 (0.451)	3	0.232 (–0.091 to 0.556)	0.170 (–0.590 to 0.929)	0.088 (59%)	0.594 (1.000)

Abbreviations: OR_F/β_F and OR_R/β_R, combined estimate of the OR (or regression coefficient β for PEF in L/min) from the fixed-effects and random-effects models, respectively, for a 10-μg/m^3 increase of pollutant; $p(I^2)$, *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.

[a] *p*-Value for Egger (Begg) bias test. [b] The metatrim command in STATA did not perform any trimming for this outcome ("no trimming performed, data unchanged").

particles PM (Seaton and Dennekamp 2003), remains to be investigated. The correlation between PM$_{10}$ and NO$_2$ varies across settings (Katsouyanni et al. 2001), with the pollution mix related to NO$_2$ generally being more variable in space and time. Notwithstanding these differences, the estimated effect size for NO$_2$ observed in this meta-analysis is similar to that of the PM$_{10}$ component, except for PEF.

There may be a concern that bias might be introduced when selecting effects that were not for the same lag. Our additional analysis for lags 0–1 provided nonsignificant estimates for NO$_2$ but significant associations with PM$_{10}$. It remains to be shown whether such a short lag is the most adequate for measuring the effect, given that higher associations may be observed at longer lags, as we found in our analysis of effect modification. Unfortunately, longer lags are less consistently reported in the literature.

Table 3. Stratum-specific combined estimates of the association of PM$_{10}$ and NO$_2$ exposure with episodes of wheezing in children symptomatic for or diagnosed with asthma.

	PM$_{10}$						NO$_2$					
	All studies			PEACE studies excluded			All studies			PEACE studies excluded		
Stratum	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)
Continent			0.066			0.457			0.366			0.084
Europe	32	1.008 (0.975–1.043)	< 0.001 (60%)	6	1.069 (1.025–1.116)	0.121 (43%)	28	0.998 (0.942–1.058)	< 0.001 (56%)	4	1.085 (1.019–1.155)	0.126 (47%)
Other	11	1.050 (1.022–1.077)	0.006 (60%)	11	1.050 (1.022–1.077)	0.006 (59%)	6	1.025 (1.014–1.036)	0.471 (0%)	6	1.025 (1.014–1.036)	0.471 (0%)
Season			0.006			0.095			0.332			0.920
Summer only	5	1.090 (1.045–1.136)	0.682 (0%)	5	1.090 (1.045–1.136)	0.682 (0%)	3	1.057 (0.987–1.133)	0.166 (44%)	3	1.057 (0.987–1.133)	0.166 (44%)
Other	38	1.020 (0.997–1.043)	< 0.001 (60%)	12	1.046 (1.022–1.071)	0.003 (61%)	31	1.016 (0.974–1.059)	< 0.001 (52%)	7	1.053 (1.015–1.092)	0.112 (42%)
Population			0.029			0.963			0.132			0.434
Asthmatics	12	1.056 (1.025–1.088)	0.009 (56%)	12	1.056 (1.025–1.088)	0.009 (56%)	7	1.034 (1.011–1.059)	0.132 (39%)	7	1.034 (1.011–1.059)	0.132 (39%)
Symptomatics	31	1.007 (0.976–1.039)	< 0.001 (62%)	5	1.055 (1.023–1.088)	0.107 (47%)	27	0.986 (0.931–1.045)	< 0.001 (54%)	3	1.056 (1.010–1.104)	0.299 (17%)
Duration			0.758			0.645			0.285			0.192
≤ 2 months	14	1.022 (0.978–1.068)	0.001 (63%)	6	1.049 (1.013–1.087)	0.069 (51%)	10	0.954 (0.819–1.110)	0.003 (64%)	2	1.098 (1.009–1.194)	0.698 (0%)
> 2 months	29	1.031 (1.005–1.058)	< 0.001 (59%)	11	1.061 (1.029–1.094)	0.003 (62%)	24	1.037 (1.009–1.066)	0.011 (44%)	8	1.036 (1.014–1.057)	0.121 (39%)
Lag			0.325			0.438			0.601			0.597
≤ 2 days	22	1.020 (0.994–1.046)	< 0.001 (64%)	11	1.047 (1.020–1.076)	0.021 (53%)	16	1.016 (0.966–1.069)	0.002 (58%)	6	1.043 (1.004–1.084)	0.190 (33%)
> 2 days	21	1.044 (1.005–1.084)	0.012 (46%)	6	1.066 (1.028–1.106)	0.072 (51%)	18	1.037 (0.981–1.096)	0.020 (45%)	4	1.061 (1.009–1.115)	0.098 (52%)
PM$_{10}$ level			0.102			0.795			0.079			0.612
< 40 µg/m^3	19	1.057 (1.020–1.095)	0.053 (37%)	9	1.057 (1.034–1.079)	0.565 (0%)	16	1.062 (1.005–1.121)	0.064 (38%)	6	1.074 (1.029–1.121)	0.319 (15%)
≥ 40 µg/m^3	23	1.016 (0.985–1.048)	< 0.001 (65%)	7	1.063 (1.021–1.106)	0.007 (66%)	17	0.982 (0.918–1.050)	0.001 (58%)	3	1.051 (0.976–1.131)	0.179 (42%)
NO$_2$ level			0.201			0.763			0.116			0.280
< 40 µg/m^3	22	1.007 (0.966–1.051)	< 0.001 (59%)	5	1.059 (1.031–1.087)	0.586 (0%)	21	0.972 (0.894–1.056)	0.002 (54%)	4	1.095 (1.034–1.159)	0.798 (0%)
≥ 40 µg/m^3	15	1.042 (1.010–1.076)	0.018 (49%)	8	1.051 (1.013–1.091)	0.038 (53%)	12	1.048 (1.002–1.097)	0.023 (50%)	5	1.053 (1.009–1.098)	0.100 (49%)
Rural/urban			0.261			0.289			0.559			0.052
Rural	18	1.008 (0.965–1.053)	< 0.001 (61%)	5	1.082 (1.022–1.145)	0.058 (56%)	14	0.997 (0.887–1.122)	0.008 (54%)	2	1.098 (1.033–1.167)	0.981 (0%)
Urban	25	1.038 (1.012–1.064)	< 0.001 (59%)	12	1.047 (1.023–1.071)	0.021 (51%)	20	1.033 (1.004–1.063)	0.007 (49%)	8	1.030 (1.012–1.049)	0.226 (25%)

Abbreviations: OR$_R$, combined estimate of the OR from the random effects model for 10-µg/m^3 increase in pollutant; $p_{\text{Strata}}p_{\text{het}}$ (I^2), *p*-value for differences between strata and *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.

Table 4. Stratum-specific combined estimates of the association of PM$_{10}$ exposure with change in PEF (L/min) and with cough episodes in children symptomatic for or diagnosed with asthma.

	PEF						Cough					
	All studies			PEACE studies excluded			All studies			PEACE studies excluded		
Stratum	*n*	β$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	β$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR$_R$ (95% CI)	p_{Strata} p_{het} (I^2)
Continent			0.041			0.750			0.001			0.047
Europe	33	0.002 (–0.182 to 0.186)	< 0.001 (72%)	5	–0.235 (–0.600 to 0.131)	0.006 (73%)	34	0.998 (0.983 to 1.014)	< 0.001 (62%)	8	1.020 (1.006 to 1.034)	0.026 (56%)
Other	7	–0.305 (–0.534 to –0.076)	0.003 (69%)	7	–0.305 (–0.534 to –0.076)	0.003 (69%)	6	1.053 (1.024 to 1.082)	0.004 (71%)	6	1.053 (1.024 to 1.082)	0.004 (71%)
Season									0.260			0.905
Summer only							2	1.039 (0.992 to 1.088)	0.602 (0%)	2	1.039 (0.992 to 1.088)	0.602 (0%)
Other	40	–0.082 (–0.214 to 0.050)	< 0.001 (72%)	12	–0.272 (–0.449 to –0.095)	< 0.001 (69%)	38	1.010 (0.996 to 1.025)	< 0.001 (70%)	12	1.035 (1.019 to 1.051)	< 0.001 (76%)
Population			0.007			0.086			0.001			0.217
Asthmatics	7	–0.549 (–0.920 to –0.177)	0.006 (67%)	7	–0.549 (–0.920 to –0.177)	0.006 (67%)	8	1.046 (1.022 to 1.071)	0.001 (70%)	8	1.046 (1.022 to 1.071)	0.001 (70%)
Symptomatics	33	0.010 (–0.159 to 0.180)	< 0.001 (73%)	5	–0.148 (–0.415 to 0.119)	0.002 (76%)	32	0.995 (0.978 to 1.013)	< 0.001 (63%)	6	1.026 (1.006 to 1.046)	0.005 (70%)
Duration			0.402			0.416			0.422			0.762
≤ 2 months	12	–0.161 (–0.394 to 0.071)	< 0.001 (67%)	4	–0.440 (–0.843 to –0.037)	0.010 (73%)	13	1.019 (0.995 to 1.043)	0.003 (59%)	5	1.034 (1.017 to 1.051)	0.188 (35%)
> 2 months	28	–0.032 (–0.225 to 0.160)	< 0.001 (74%)	8	–0.241 (–0.500 to 0.018)	0.079 (69%)	27	1.007 (0.990 to 1.026)	< 0.001 (70%)	9	1.038 (1.017 to 1.059)	< 0.001 (77%)
Lag			0.325			0.189			0.018			0.030
≤ 2 days	14	–0.167 (–0.354 to 0.021)	< 0.001 (70%)	8	–0.203 (–0.426 to 0.020)	0.001 (71%)	19	0.997 (0.979 to 1.014)	< 0.001 (74%)	6	1.022 (1.006 to 1.038)	0.004 (71%)
> 2 days	26	–0.025 (–0.237 to 0.187)	< 0.001 (73%)	4	–0.396 (–0.578 to –0.214)	0.392 (0%)	21	1.036 (1.009 to 1.065)	0.001 (56%)	8	1.067 (1.030 to 1.106)	0.001 (71%)
PM$_{10}$ level			0.774			0.344			0.706			0.173
< 40 µg/m^3	14	–0.021 (–0.441 to 0.398)	< 0.001 (68%)	4	–0.116 (–0.613 to 0.381)	0.006 (76%)	17	1.006 (0.983 to 1.029)	0.002 (57%)	7	1.022 (1.004 to 1.041)	0.047 (53%)
≥ 40 µg/m^3	25	–0.086 (–0.233 to 0.061)	< 0.001 (74%)	7	–0.380 (–0.607 to –0.152)	0.005 (68%)	22	1.012 (0.991 to 1.033)	< 0.001 (74%)	6	1.045 (1.018 to 1.073)	< 0.001 (79%)
NO$_2$ level			0.722			0.028			0.012			0.031
< 40 µg/m^3	21	–0.018 (–0.278 to 0.242)	68%*	3	0.144 (–0.224 to 0.512)	0.155 (46%)	20	0.980 (0.954 to 1.007)	< 0.001 (60%)	3	1.013 (1.001 to 1.025)	0.342 (7%)
≥ 40 µg/m^3	11	–0.091 (–0.399 to 0.216)	80%*	3	–1.085 (–2.120 to –0.051)	0.028 (72%)	13	1.032 (1.001 to 1.064)	< 0.001 (72%)	6	1.065 (1.019 to 1.113)	< 0.001 (82%)
Rural/urban			0.911			0.433			0.116			0.604
Rural	18	–0.125 (–0.286 to 0.036)	< 0.001 (65%)	4	–0.301 (–0.507 to –0.096)	0.020 (70%)	17	0.994 (0.968 to 1.021)	< 0.001 (65%)	4	1.050 (0.995 to 1.109)	0.003 (79%)
Urban	21	–0.108 (–0.360 to 0.144)	< 0.001 (75%)	7	–0.473 (–0.851 to –0.095)	0.008 (66%)	23	1.020 (1.002 to 1.039)	< 0.001 (69%)	10	1.035 (1.017 to 1.052)	< 0.001 (70%)

Abbreviations: OR$_R$/β$_R$, combined estimate of the OR (or regression coefficient β for PEF in L/min) from the random effects model for a 10-µg/m^3 increase in pollutant; $p_{\text{Strata}}p_{\text{het}}$ (I^2), *p*-value for differences between strata and *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.
$^*p < 0.001$.

There are limitations of the panel studies we have considered. When evaluating symptoms, the possibility of a confounding role of medications should be considered. Medication use on polluted days may influence symptoms and lung function. Although the PEACE studies found no correlation between the number of children using asthma medication and air pollution levels (Roemer et al. 2000), this does not account for the possibility that asthmatic children increase the dose on such days. Information regarding this possibility is generally missing in the individual study reports. The evaluation of the effect on PEF is difficult because of the large between-individual variability of this indicator that is likely to be strongly influenced by medication use among diseased subjects. Finally, another difficulty is that the measured pollutants are only part of a more complex air pollution mixture, and the effects of "PM_{10}" and "NO_2" may vary among studies and may be a less or more adequate measure of the effects of air pollution. In a meta-analysis, it is not possible to adequately assess the problems related to these mixes. Multipollutant (mostly two-pollutant) models were calculated for only 10 of the study populations, and the combinations of the pollutants varied among studies. Only if the raw data were available for all studies could one attempt to tease out individual pollutant effects and also avoid overestimation of the individual effect. It will nonetheless be a daunting task, because in most cases criteria air pollutants are measured, which may be indicators of different unmeasured compounds in different areas. Delfino et al. (2003) reported, for example, that the effect of "PM_{10}" was lower when, for example, organic carbon, benzene, or *m*,*p*-xylene was included in two-pollutant models. This may be a general finding, or it may be typical for the region investigated. The results presented here therefore are not to be strictly understood as the effect of PM_{10} only or NO_2 only; the greater context must be borne in mind.

We observed a high degree of heterogeneity among the investigated studies. Stratifying by the identified effect modifiers reduced the heterogeneity only to some extent. We obtained the greatest reduction in heterogeneity when using the same lag for all studies. Sources of heterogeneity may be linked to various design aspects of the study, such as the inclusion criteria for the panel, duration of the study, and the analytical strategies. For the PEACE study with its standardized study protocol and common analytical strategy, we calculated an I^2 ranging from 40% to 79% depending on the outcome/pollutant only for the analysis using different lags, whereas the analyses with the uniform shorter lag reduced the heterogeneity among PEACE studies for symptoms and PEF (data not shown). Although this may highlight the importance of a standardized study protocol, caution is needed until it is better known which lag is the most appropriate. Therefore, other potential sources of the observed heterogeneity, such as differences in the air pollution mix related to spatial or temporal variability, may still be of importance even in well-standardized studies. Different baseline characteristics of the populations studied may also have their influence.

The estimated effect of PM_{10} on asthma was higher in studies that were conducted in the summer. The composition of the air pollution mix may also be the reason for higher observed effects of PM_{10} in studies that have been conducted in summer only. Summer pollution is qualitatively different from winter pollution: O_3 levels are higher, and in general the air pollution mixture is more strongly influenced by photochemical reaction. Ward and Ayres (2004) observed in their analysis a higher estimated effect in studies conducted in periods of high O_3 levels. A time-series analysis of Atkinson et al. (2001) observed effect modification by O_3 for hospital admission for respiratory conditions in persons older than 65 years, although not for asthma admissions in children or adults. Alternative reasons could be that the PM_{10} effect is confounded by the effect of O_3. However, independent effects have been found for $PM_{2.5}$, and for $PM_{2.5–10}$ concerning cough [for a more detailed discussion, see Ward and Ayres (2004)]. The higher estimated effect of PM_{10} in the summer could also be linked to more (active) time spent outside, which could act in several ways. First, it would reduce misclassification due to less exposure to indoor conditions. Second, it could increase the effect of PM_{10} through increased inhalation during the activities outside (e.g., exercise), which also could increase the effect of O_3.

Consideration of longer lags did result in elevated associations of PM_{10} with cough. This seems plausible because air pollution may act not only as a short-term trigger but also as a priming event by inducing processes of enhanced airways inflammation (Kimber 1998) that will build up over a period of hours to days and result in subsequent bronchial hyperreactivity (Mortimer et al. 2002). Indeed, lengthy lag periods have been found in panel studies as well as time-series studies of emergency department visits (Halonen et al. 2008; Mortimer et al. 2002).

Continent modified the association of PM_{10} with cough; we found a significant combined effect only for the studies outside of Europe, whereas for the European studies the combined effect was null (OR = 0.998; 95% CI, 0.983–1.014). This estimate is similar to that reported by Anderson et al. (2004) for Europe (OR = 0.999; 95% CI, 0.987–1.011). At first glance, a similar effect modification was present for asthma symptoms, but this disappeared after exclusion of the PEACE studies. It therefore remains speculative whether this is really an effect for Europe or is attributable to some other characteristic that is specifically related to the PEACE study.

Nevertheless, a stronger association of PM_{10} with respiratory symptoms reported in the United States compared with Europe was also observed in an earlier meta-analysis, conducted before the PEACE study, that also included healthy children (Dockery and Pope 1994). One plausible explanation could be different pollutant mixes on the two continents. The extent to which these differences are systematic and will provide relevant information remains to be investigated, given that also within the United States and within Europe there are marked differences concerning the air pollution mix, which may result in differing health effects via effect modification or due to a different composition of PM_{10} (Katsouyanni et al. 2001; Levy et al. 2000).

In our analysis, we found the association of PM_{10} with cough to be stronger for higher ambient NO_2 concentration. However, we did not see this effect in the analysis restricted to lags 0–1, but in this latter analysis we found higher associations at higher NO_2 levels with asthma symptoms. Effect modification by NO_2 has been found in time series studies on mortality in Europe (Katsouyanni et al. 2001), and to a lesser extent in the United States (Levy et al. 2000). It has been discussed that NO_2 is a marker for a certain air pollution mixture, notably arising from traffic, which is more noxious for health.

Conclusion

Our meta-analysis provides strong evidence for an effect of PM_{10} as an aggravating factor of asthma in children. Although there is no firm toxicologic evidence of adverse health effects of NO_2 at ambient levels to date, the epidemiologic results suggest an adverse effect of NO_2 on respiratory health in children with asthma. However, caution is needed in the final conclusion for NO_2 because the association with asthma attacks was not robust to lag specification. The finding may reflect the fact that NO_2 is associated at extended lags, or it may be only an artifact due to our method of choosing the specific lag to be included in the meta-analysis. More consistent reporting of longer lags is needed in panel studies to better judge the effect of monitored outdoor NO_2. The results of the study support the need to protect asthmatic children with strict air quality standards for PM_{10} and, considering the precautionary principle, also for NO_2.

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Short-Term Effects of PM_{10} and NO_2 on Respiratory Health among Children with Asthma or Asthma-like Symptoms: A Systematic Review and Meta-Analysis

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Objective: Our goal was to quantify the short-term effects of particulate matter with aerodynamic diameter ≤ 10 μm (PM_{10}) and nitrogen dioxide (NO_2) on respiratory health of asthmatic children from published panel studies, and to investigate the influence of study and population characteristics as effect modifiers.

Data extraction: After a systematic literature review, we extracted quantitative estimates of the association of PM_{10} and/or NO_2 with respiratory symptoms and peak expiratory flow (PEF). Combined effect estimates for an increase of 10 μg/m^3 were calculated by random effects meta-analysis for all studies and for different strata defined by study characteristics. The effect of publication bias was investigated with Egger's and Begg's tests and "trim-and-fill" analyses.

Data synthesis: We identified 36 studies; 14 were part of the European Pollution Effects on Asthmatic Children in Europe (PEACE) study. Adverse associations of PM_{10} with asthma symptoms were statistically significant [odds ratio (OR) = 1.028; 95% confidence interval (CI), 1.006–1.051]. There were also associations, although not statistically significant, of PM_{10} with cough (OR = 1.012; 95% CI, 0.997–1.026) and on PEF (decrease of –0.082 L/min; 95% CI, –0.214 to 0.050). NO_2 had statistically significant associations with asthma symptoms in the overall analysis considering all possible lags (OR = 1.031; 95% CI, 1.001–1.062), but not when we evaluated only the 0–1 lag. We found no publication bias, although it appeared when excluding the PEACE studies. When we applied the trim-and-fill method to the data set without the PEACE studies, the results were similar to the overall estimates from all studies. There was an indication for stronger PM_{10} associations for studies conducted in summer, outside of Europe, with longer lags, and in locations with higher NO_2 concentrations.

Conclusions: We found clear evidence of effects of PM_{10} on the occurrence of asthma symptom episodes, and to a lesser extent on cough and PEF. The results for NO_2 are more difficult to interpret because they depend on the lag times examined. There was an indication of effect modification by several study conditions.

Key words: air pollution, asthma, children, NO_2, PM, short-term effects. *Environ Health Perspect* 118:449–457 (2010). doi:10.1289/ehp.0900844 [Online 12 November 2009]

Particulate matter (PM) with an aerodynamic diameter ≤ 10 μm (PM_{10}) and nitrogen dioxide (NO_2) are important ambient air pollutants regulated by European and national legislations. Measurements of PM_{10} include PM of different aerodynamic diameter (coarse, fine, and ultrafine PM), and the size distribution is related to the emission source, with the coarse fraction mainly originating from soil and natural sources and fine and ultrafine PM mainly originating from combustion or being secondary aerosols from sources that can be far away (Williams 1999). Notwithstanding possible long-range transport, most of NO_2 in the ambient air arises from oxidization of emitted NO_x from combustion mainly from motor engines in urban areas (Williams 1999), and it is considered to be a good marker of traffic-related air pollution.

The health effects of PM_{10} and NO_2 have been extensively reviewed, and air quality standards and guidelines have been proposed to protect public health [U.S. Environmental Protection Agency (EPA) 2005, 2008a; World Health Organization (WHO) Regional Office for Europe 2000, 2006]. Nevertheless, important clinical effects are currently detectable in real-life exposure to traffic-related pollutants among susceptible subgroups of the population, such as individuals with asthma. A recent study from London has clearly shown that asthmatic adults have a significant decrease in lung function after 2 hr of walking along a street in the center of London as opposed to walking in a nearby park (McCreanor et al. 2007). The effects were stronger in individuals with moderate asthma compared with individuals with mild asthma. Several studies have been conducted among children with asthma focusing on the short-term effects of air pollution, that is, its effects on daily symptoms and lung function. Most studies used air pollution measurements from central monitoring sites that provide daily data. Mostly PM_{10}, NO_2, and ozone (O_3) have been evaluated; results for carbon monoxide, black smoke, and $PM_{2.5}$ (PM with aerodynamic diamter ≤ 2.5 μm) have been less reported to date. Studies on long-term effects typically involve proximity of the residence to roads, but they do not provide information on short temporal scales.

Both PM_{10} and NO_2 have been associated with increases in the frequency of asthma symptoms and with lung function decrements in children on a day-to-day scale (Gielen et al. 1997; Ostro et al. 2001; Pope and Dockery 1992; Roemer et al. 1993; Romieu et al. 1996; Schildcrout et al. 2006; van der Zee et al. 1999; Vedal et al. 1998). However, the results of the existing studies have not been consistent, and a comprehensive quantitative evaluation of the respiratory effect in children is still lacking.

Two meta-analyses on the short-term effects of PM_{10} on children's respiratory health have previously been performed (Anderson et al. 2004; Ward and Ayres 2004). Anderson et al. (2004) reviewed the effects on cough and medication use in European panel studies, a large number of which were conducted within the multicenter PEACE (Pollution Effects on Asthmatic Children in Europe) study that provided 28 of the 34 effect estimates. In their review, they found no effect of PM_{10} on cough in children [odds ratio (OR) = 0.999 for 10-μg/m^3 increase in PM_{10}; 95% confidence interval (CI), 0.987–1.011]. Ward and Ayres (2004) performed a meta-analysis of worldwide panel studies published through 2002 that included asthmatic and healthy children. They found a significant effect of PM_{10} on cough (OR = 1.004 per unit μg/m^3 increase PM_{10}; 95% CI, 1.002–1.006), on lower respiratory symptoms (LRS) or wheeze (OR = 1.004 per 1 μg/m^3 PM_{10}; 95% CI, 1.002–1.005), and on peak expiratory flow (PEF) (a decrease of –0.033 L/min per 1 μg/m^3 in PM_{10}; 95% CI, –0.019 to –0.047). In both meta-analyses, the results of the large multicenter European PEACE study had a strong influence because of its primarily null results.

To our knowledge, no quantitative meta-analysis on the effects of NO_2 among children with asthma has so far been performed. The available evidence is inconsistent, with some studies showing a detrimental effect

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of NO_2 on symptoms or lung function and other investigations indicating no effect (Ackermann-Liebrich and Rapp 1999).

To provide a quantitative estimate of the acute effects of short-term exposure to PM_{10} and NO_2 on respiratory symptoms and lung function in asthmatic children, we performed a meta-analysis on panel studies published through July 2008. We assessed the role of the PEACE study on the overall evaluation, and we paid specific attention to the influence of publication bias. Because study characteristics and pollution mixtures vary with space and time, some heterogeneity among the study results conducted at different locations is to be expected. We therefore investigated the influence of study and population characteristics on the outcomes.

Methods

We conducted a systematic search of the literature from 1990 through July 2008 that focused on the short-term effects of outdoor NO_2 and PM_{10} on respiratory health outcomes as determined in panel studies. To focus our study, we did not consider exposure to O_3 or studies on indoor exposure; the latter has been typically investigated for long-term effects. We investigated lung function as measured by PEF and symptoms of cough and asthma, the latter being reported as wheeze or LRS. A MEDLINE (National Library of Medicine 2008) search was carried out; the search strings consisted of "asthma OR wheeze OR cough OR bronchitis OR lung function," "air AND pollut*," and "PM_{10} OR PM(10)" and "NO2 OR "NO(2)" OR "nitrogen dioxide." Limits were set to retrieve only children ("All Child 0–18 years"). The exact search history is available from the authors. These criteria were applied to maximize sensitivity and to not miss any relevant publication. The age range of children in the panel studies was 5–19 years. Wheezing among infants was not considered because the asthma phenotype differs in very young children and there are essentially no panel studies on infants.

The references were then selected by hand according to the following inclusion/exclusion criteria: exclusion of indoor and laboratory studies; inclusion of panel studies on asthmatic or symptomatic (see definition below) children that reported a quantitative effect (regression coefficients); inclusion of only one publication of the same study/database for each outcome. With regard to the statistical analysis, we included only studies that controlled for the effect of daily temperature and day of the week, because these are important confounders and should be adjusted for to detect short-term effects of air pollution.

For the definition of "asthmatics" or "symptomatic" children, we relied on the criteria reported in the individual publications. Generally, children with asthma confirmed by a physician or who were referred from clinics, school nurses, and so on, with an asthma diagnosis were classified as "asthmatics." We considered "symptomatic" children who reported, mostly in a questionnaire, wheezing or cough apart from cold or an asthma diagnosis, or who took medication for asthma.

The evaluated outcomes were "asthma symptoms" and "cough," and the definitions differed in various studies, as indicated in "Results." For PEF, we included only studies that reported changes as liters per minute or that allowed us to calculate the changes in liters per minute from the given percentages and were therefore directly comparable. Other lung function parameters and exhaled nitrogen oxide were not considered, because these studies are relatively scarce.

For the meta-analysis, we used the coefficients derived from single-pollutant models. Where necessary, the coefficient estimates were recalculated to reflect a 10-$\mu g/m^3$ increase in pollutant assuming a linear relationship over the considered range. When coefficients for different lag times were given, we used the one that resulted in a statistically significant effect or, when all estimates were either significant or not significant, the lag reflecting the highest effect size. The same criterion was applied if lung function measurements were performed in the morning and in the evening. These criteria were modified in a sensitivity analysis as indicated below.

Combined estimates of the natural logarithm of the OR for respiratory symptoms and the linear regression coefficients for PEF, respectively, were calculated for all studies with a fixed effects and a random effects meta-analysis model (DerSimonian and Laird 1986; Petitti 2001) using the meta command of STATA (releases 8 and 9.1; StataCorp., College Station, TX, USA). This command uses inverse-variance weighting to calculate combined estimates. Although a fixed-effects model assumes that the studies reflect the same underlying average effect, in a random-effects model the study effects are coming from a common underlying distribution of effects. The corresponding weights include an additional term that reflects the between-study heterogeneity due to unexplained sources. Heterogeneity was assessed by calculating the I^2 of Higgins and Thompson, which reflects the proportion of total variation in the combined estimate that is due to heterogeneity between studies (Higgins and Thompson 2002).

We evaluated publication bias with both the Begg test and the Egger test (Begg and Mazumdar 1994; Egger et al. 1997). The Egger et al. regression asymmetry test tends to suggest the presence of publication bias more frequently than the Begg adjusted rank correlation test, which has a low power.

Where necessary, a trim-and-fill analysis was performed to take account of publication bias (Duval 2000). This procedure estimates the number and outcomes of theoretical missing studies and incorporates them into the meta-analysis. All the calculations were done using the metabias and metatrim commands in STATA.

To explore heterogeneity in meta-analysis estimates, we considered the influence of the following study characteristics on meta-analytical estimates: continent (Europe; other countries), season (summer only; any other cases), population [asthmatics (confirmed diagnosis); symptomatics], duration (≤ 2 or > 2 months), lag (≤ 2 or > 2 days), average PM_{10} levels (< 40 or ≥ 40 $\mu g/m^3$), and average NO_2 levels (< 40 or ≥ 40 $\mu g/m^3$). The influence of study characteristics was investigated by calculating the combined effect for each stratum and evaluating the difference between strata-specific estimates. The null hypothesis that the difference between the estimates from the two strata equals 0 was tested (with Z-score), and the corresponding p-value is reported here. Statistical significance was defined as $p < 0.05$ for all analyses.

Because the choice of the lag was a critical step, we performed additional analyses using, for all the studies, the effect estimate at lag 0–1 (instead of the most significant lag). The following criteria were applied. The default was lag 1; if lag 1 was not available, lag 0 or lag 0–1 was considered instead. In addition, we calculated the combined effects for PEF using only the evening values.

Results

We retrieved a total of 77 references for PM_{10} and 324 for NO_2. Applying the inclusion/exclusion criteria outlined in "Materials and Methods," 36 studies on PM_{10} and 24 on NO_2 remained to be included in the meta-analysis (Table 1). Some of the excluded studies were on indoor NO_2, notably related with cooking and heating. Other studies were time-series analyses on hospital admissions, and a few studies were on pathologic mechanisms and exposure assessment. Of the total of 36 studies (on 51 populations), 14 were PEACE studies (28 populations). In this review, we refer to each population as a separate study and use the corresponding estimates. Peacock et al. (2003) studied a subgroup of wheezy children but did not give estimates for the coefficient for this group. Nevertheless, because the authors stated that there was no effect modification by wheeze, we took the estimate for all children instead.

Of the total of 51 populations studied, 36 were from Europe and 15 from elsewhere, mainly the United States. Thirty populations were from urban areas, and 20 studies were conducted in rural environments (one unspecified). Four studies were carried out in the summer only; the other studies were conducted mainly in winter or during most of the year. The mean 24-hr average for NO_2 ranged from 8 to 77 µg/m^3, and the mean 24-hr average for PM_{10} ranged from 11 to 167 µg/m^3 (but only Mexico City had a value of 167 µg/m^3; all the others had a value < 100 µg/m^3).

The definition of the outcome regarding asthma symptoms varied among the studies: We included the estimates for wheeze from five studies (Jalaludin et al. 2004; Roemer et al. 1993; Romieu et al. 1996, 1997; Vedal et al. 1998); 35 studies used a variable "lower respiratory symptoms" or "asthma symptoms," which in most studies (including PEACE studies) consisted of wheezing, shortness of breath, and asthma attacks (Gielen et al. 1997; Ostro et al. 2001; Pope and Dockery 1992; Roemer et al. 1998b; van der Zee et al. 1999). Other studies also included chest tightness (Delfino et al. 1998, 2002, 2003; Mortimer et al. 2002; Yu et al. 2000), sputum production (Delfino et al. 2002, 2003), or cough (Delfino et al. 1998, 2002, 2003; Mortimer et al. 2002; Ostro et al. 2001; Pope and Dockery 1992;

Table 1. Study characteristics of the panel studies.

Study	Outcomes studied^a	Pollutant studied	Year of study	Continent	Urban/rural	*n* (duration in days)	Season	Population	Pollutant 24-hr mean (µg/m^3)^b	
									PM_{10}	NO_2
Pope and Dockery 1992	LRS, cough, PEF	PM_{10}	1990	Other	Rural	39 (70)	Other	Symptomatics	56	—
Roemer et al. 1993	LRS, cough, PEF	PM_{10}	1990	Europe	Rural	73 (90)	Other	Symptomatics	76	71^c
Romieu et al. 1996	LRS, cough, PEF	PM_{10}	1991	Other	Urban	71 (60)	Other	Asthmatics	167	75
Gielen et al. 1997	LRS, cough	PM_{10}	1995	Europe	Urban	61 (60)	Summer only	Asthmatics	31	—
Peters et al. 1997	Cough, PEF	PM_{10}	1991	Europe	Urban	89 (210)	Other	Asthmatics	55	—
Romieu et al. 1997	LRS, cough, PEF	PM_{10}	1991	Other	Urban	67 (60)	Other	Asthmatics	54	37–169^d
Delfino et al. 1998	LRS	PM_{10}	1995	Other	Rural	24 (90)	Summer only	Asthmatics	43	—
Segala et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1992	Europe	Urban	41 (175)	Other	Asthmatics	34	57
Vedal et al. 1998	Cough, PEF	PM_{10}	1990	Other	Rural	75 (492)	Other	Asthmatics	27	—
Tiittanen et al. 1999	Cough, PEF	PM_{10}	1995	Europe	Urban	49 (42)	Other	Symptomatics	50%ile, 28	50%ile, 15
van der Zee et al. 1999	LRS, cough	PM_{10}, NO_2	1993	Europe	Urban	142 (90)	Other	Symptomatics	38	49
van der Zee et al. 1999	LRS, cough	PM_{10}, NO_2	1993	Europe	Rural	178 (90)	Other	Symptomatics	31	27
Jalaludin et al. 2000	PEF	PM_{10}, NO_2	1994	Other	Urban	125 (300)	Other	Asthmatics	23	28
Yu et al. 2000	LRS	PM_{10}	1993	Other	Urban	133 (58)	Other	Asthmatics	10	—
Ostro et al. 2001	LRS, cough	PM_{10}, NO_2	1993	Other	Urban	138 (90)	Summer only	Asthmatics	51	77^c
Delfino et al. 2002	LRS	PM_{10}, NO_2	1996	Other	Rural	22 (61)	Other	Asthmatics	20	26^c
Just et al. 2002	LRS, cough	PM_{10}, NO_2	1996	Europe	Urban	82 (90)	Other	Asthmatics	24	54
Mortimer et al. 2002	LRS	PM_{10}, NO_2	1993	Other	Urban	846 (14)	Summer only	Asthmatics	—	61
Aekplakorn et al. 2003	PEF	PM_{10}	1997	Other	Rural	88 (53–61)	Other	Asthmatics	50%ile, 22–25^e	No NO_2 measured
Delfino et al. 2003	LRS, PEF	PM_{10}, NO_2	1999	Other	Urban	22 (90)	Other	Asthmatics	60	8^c
Peacock et al. 2003	PEF	PM_{10}, NO_2	1996	Europe	—	179 (63)	Other	Symptomatics	18–23^e	31–36^e
Jalaludin et al. 2004	LRS, cough	PM_{10}, NO_2	1994	Other	Urban	148 (> 30)	Other	Symptomatics	23 (0600–2100 hr)	28 (0600–2100 hr)
Schildcrout et al. 2006	LRS	PM_{10}, NO_2	1993	Other	Urban	990 (60)	Other	Asthmatics	50%ile, 18–34^e	50%ile, 34–59^e
PEACE studies										
Baldini et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	68 (65)	Other	Symptomatics	62	68
Baldini et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	60 (65)	Other	Symptomatics	70	33
Beyer et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	75 (172)	Other	Symptomatics	40	27
Beyer et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	63 (172)	Other	Symptomatics	33	26
Clench-Aas et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	56 (70)	Other	Symptomatics	19	49
Clench-Aas et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	68 (70)	Other	Symptomatics	11	21
Englert et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	50 (58)	Other	Symptomatics	52	38
Englert et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	66 (58)	Other	Symptomatics	43	21
Forsberg et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	75 (84)	Other	Symptomatics	13	25
Forsberg et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	72 (84)	Other	Symptomatics	12	15
Haluszka et al. 1998	LRS, cough, PEF	PM_{10}	1993	Europe	Urban	73 (82)	Other	Symptomatics	60	—
Haluszka et al. 1998	LRS, cough, PEF	PM_{10}	1993	Europe	Rural	76 (76)	Other	Symptomatics	56	—
Kalandidi et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	87 (60)	Other	Symptomatics	99	75
Kalandidi et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	80 (60)	Other	Symptomatics	50	20
Kotesovec et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	91 (60)	Other	Symptomatics	74	49
Kotesovec et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	77 (60)	Other	Symptomatics	32	13
Nielsen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	78 (60)	Other	Symptomatics	23	21
Nielsen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	82 (60)	Other	Symptomatics	16	9
Niepsuj et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	72 (83)	Other	Symptomatics	69	69
Niepsuj et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	73 (83)	Other	Symptomatics	74	70
Rudnai et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	76 (61)	Other	Symptomatics	61	35
Rudnai et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	63 (67)	Other	Symptomatics	52	25
Timonen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	85 (72)	Other	Symptomatics	18	28
Timonen et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	84 (72)	Other	Symptomatics	13	14
Vondra et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Urban	66 (85)	Other	Symptomatics	53	45
Vondra et al. 1998	LRS, cough, PEF	PM_{10}, NO_2	1993	Europe	Rural	68 (85)	Other	Symptomatics	50	13
van der Zee et al. 1998	PEF	PM_{10}, NO_2	1993	Europe	Urban	55 (101)	Other	Symptomatics	45	46
van der Zee et al. 1998	PEF	PM_{10}, NO_2	1993	Europe	Rural	71 (93)	Other	Symptomatics	44	27

[a] LRS is equivalent to asthma symptoms. [b] Mean of the 24-hr means unless otherwise indicated. [c] Extrapolated from 1-hr maximum. [d] Range of means over the study period. [e] Means from more than one location.

Yu et al. 2000). In the latter studies, no separate effect estimate for cough was given except by Pope and Dockery (1992). Cough was not more precisely defined except for nocturnal cough (Just et al. 2002), cough during the day or the previous night (Peters et al. 1997), and wet and dry cough (Pope and Dockery 1992).

The effect estimates extracted from the individual studies are given in the Supplemental Material, Table 1 (doi:10.1289/ehp.0900844) and are illustrated in Figures 1–3, which also give the combined effects calculated in the meta-analysis. When we considered all the studies in the fixed-effects models, we found a significant increase of 2.3% in asthma symptoms, 1.4% for cough, and –0.117 min/L for PEF for a 10-μg/m^3 increase in PM_{10} (Table 2). However, we observed a considerable degree of heterogeneity among the studies, with I^2 ranging from 35% to 77%. Therefore, the estimates based on the random effects model are likely to represent the overall effect more accurately. For an increase of 10 μg/m^3 of PM_{10}, we found a significant increase of 2.8% in asthma symptoms, and an increase for cough (1.2%) and a decrease of PEF (–0.082 L/min) that were borderline significant. For an increase of 10 μg/m^3 NO_2, we found a significant increase in asthma symptoms of 3.1%. We found no clear association of NO_2 with cough or PEF; only when we excluded the PEACE studies did we find evidence of effect for NO_2 on cough.

When we considered all the studies, we found no evidence of publication bias. When we excluded the PEACE studies, publication bias was present for asthma symptoms for PM_{10} and NO_2; after applying the trim-and-fill procedure, the random-effects estimates decreased from 5.5% to 3.5% and from 3.9 to 3.2, respectively, and were therefore similar to the estimates for all studies. We also saw a tendency for a similar publication bias for cough (PM_{10} and NO_2), with significant values for the Egger test but not for the Begg test. However, the resulting trim-and-fill estimates for cough were more similar to those of the non-PEACE studies than to that for all studies (Table 2).

We found an effect modification of the effect of PM_{10} on asthma symptoms by continent (stronger association outside Europe), season (stronger association in studies carried out in summer only), study population (stronger effect among asthmatic children), and PM_{10} level (stronger association at levels < 40 μg/m^3) (Table 3). When we excluded the PEACE studies, only season remained near significance ($p < 0.1$). For the effect of PM_{10} on cough (Table 4), there were higher associations in studies conducted outside of Europe, with lag > 2 days, or with higher NO_2 levels; these effect modifications remained when excluding the PEACE studies. For the effect of PM_{10} on PEF (Table 4), there was a tendency for a higher decrease in PEF in asthmatic than in symptomatic children. We found no consistent effect modification, and there was no evidence for effect modification of the association between NO_2 and any of the investigated outcomes s (Table 3 for asthma; for cough and PEF, data not shown).

The results of the sensitivity analyses based on the predefined lag 0–1 (i.e., lag 1 or 0 or 0–1) and on evening PEF showed mostly a similar pattern, especially for PM_{10}, although the associations were generally weaker [see Supplemental Material, Table 3 (doi:10.1289/ehp.0900844)]. However, the associations of NO_2 with asthma symptoms and cough were not significant in this analysis. We found effect modification even when we omitted the PEACE studies (see Supplemental Material, Tables 4 and 5), for the effect of NO_2 on asthma symptoms, with higher associations for asthmatics

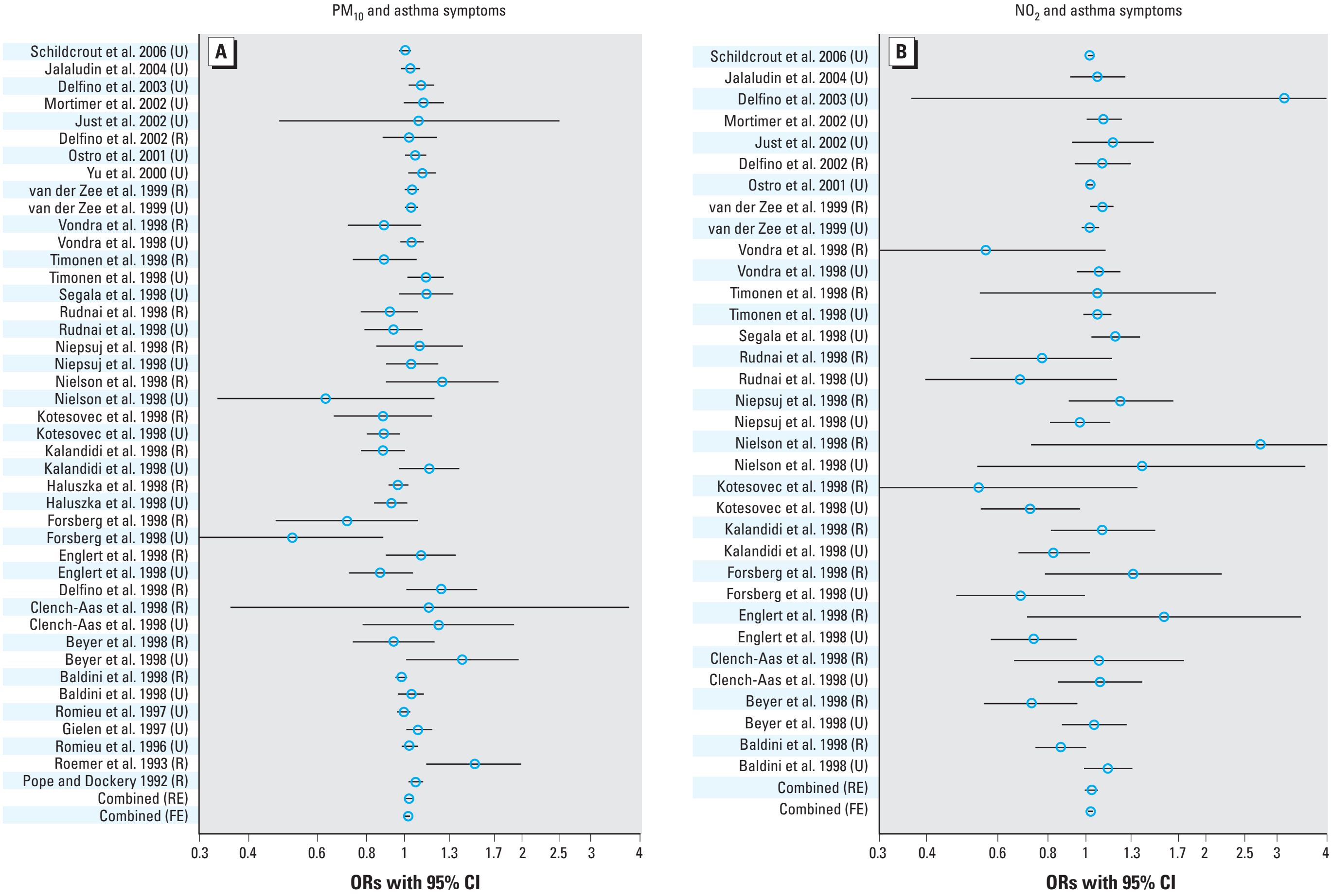

Figure 1. ORs with 95% CIs for the association between a rise of 10 μg/m^3 PM_{10} (*A*) or NO_2 (*B*) and the occurrence of asthma symptoms. Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

and during the summer (the latter based on two studies in one stratum). Furthermore, the estimated effects of PM_{10} on asthma symptoms were higher at higher concentrations of NO_2.

Discussion

Our meta-analysis shows effects of PM_{10} on both asthma symptoms and cough. We found no indication of publication bias when we considered all the evidence. For NO_2, we found statistically significant associations with asthma symptoms in the overall analysis but not in the sensitivity analysis restricted to the 0–1 lags. The effects of air pollutants on PEF were limited to PM_{10}, and we saw a stronger association when we excluded the PEACE studies from the analysis. We found an indication of effect modification of PM_{10}, with higher associations with asthma symptoms during summer and with cough for studies conducted outside of Europe, for a lag > 2 days, and at higher ambient NO_2 concentrations. When considering lags 0–1 only, the pattern of effect modification was different.

A previous meta-analysis considered panel studies in children and summarized the evidence for PM_{10} up through June 2002 (Ward and Ayres 2004). Our meta-analysis extends this work further up through July 2008, adding 11 studies. On the other hand, we did not include nine studies (two from Europe) included in the Ward and Ayres (2004) analysis because the panels evaluated asymptomatic children and we focused specifically on children with asthma. Our estimates of the PM_{10} effect on asthma symptoms and cough are similar to those of the previous meta-analysis [1.04 and 1.028 for asthma symptoms, 1.04 and 1.031 for cough in Ward and Ayres (2004) and in our analysis, respectively]. Our random effects estimate for PEF is weaker than that from Ward and Ayres (–0.082 vs. –0.33 L/min for a 10-µg/m^3 increase), whereas the fixed effects estimates are similar (–0.117 vs. –0.12 L/min).

We found no publication bias when considering all studies. However, excluding the PEACE studies, which highly influenced the estimates from the meta-analyses, resulted in clear publication bias for asthma symptoms, but less so for cough. The PEACE studies reported, on average, no effects of air pollution, with very few individual centers showing an association with PM_{10} (Roemer et al. 1998a). It is, on the one hand, the only multicenter series of studies that has been conducted with a unified protocol and whose results are not biased by publication procedures. On the other hand, limitations of the PEACE study have to be considered (Roemer et al. 1998a, 2000). There is concern that the entire study series might have been influenced by an influenza epidemic during the study period. If the study period is relatively short (e.g., 2 months as in the PEACE study), such unexpected events might confound the results, and it is generally more difficult to adjust adequately for time trend. In our analyses, we found no significant difference between studies with durations longer or shorter than 2 months. Nevertheless, for asthma symptoms, the estimate from the studies with durations longer than 2 months was slightly higher and statistically significant. In the Netherlands, where the data was collected during three winters instead of just one, there were clear effects of air pollution in symptomatic children (Roemer et al. 2000; van der Zee et al. 1999). In addition, all PEACE studies were carried out in the winter, when the effect of respiratory infections will putatively be greater compared with summer. Furthermore, in our analysis, we have found statistically greater associations in summer for asthma symptoms.

To the best of our knowledge, this is the first meta-analysis for effects related to

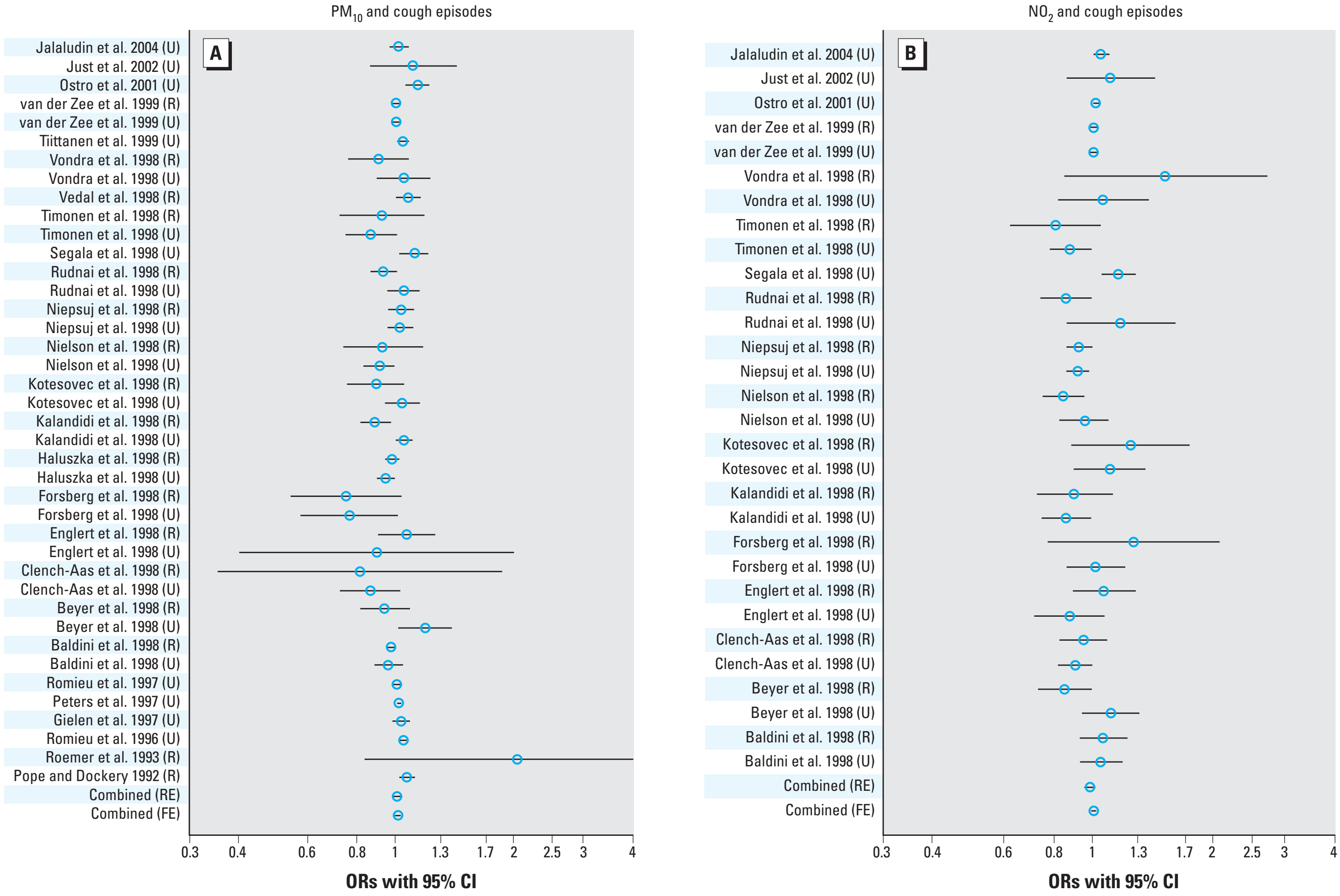

Figure 2. ORs with 95% CIs for the association between a rise of 10 µg/m^3 PM_{10} (*A*) or NO_2 (*B*) and the occurrence of cough episodes. Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

monitored outdoor NO_2 on respiratory health in asthmatic children, although the main investigations on NO_2 have been extensively reviewed (U.S. EPA 2008b; WHO Regional Office for Europe 2006). *In vitro* studies at comparatively low concentrations of NO_2, but still notably higher than ambient levels (400 ppb or 760 µg/m^3), have shown cell damage accompanied by release of cytokines, such as tumor necrosis factor-α and interleukin-8 (Devalia et al. 1993). In controlled human studies, the same concentration for 1 hr led to an increased early and late asthmatic response (measured by forced expiratory volume in 1 sec) after challenge with house dust mite allergen compared with ordinary air (Tunnicliffe et al. 1994). Similarly, a 30-min exposure to 500 µg/m^3 NO_2 increased the early-phase response to an otherwise nonsymptomatic allergen dose (Strand et al. 1998). Although such concentrations can be reached during some episodes, the usual ambient concentrations of NO_2 are lower. On the other hand, several studies on hospital admissions and emergency department visits for asthma conducted in Europe and elsewhere [reviewed by U.S. EPA (2008b); WHO Regional Office for Europe (2006)] did find an independent effect of NO_2. Therefore, the extent to which the observed associations are related to a direct effect of NO_2 and/or reflect the fact that NO_2 is a marker for the urban pollution mix, particularly for ultrafine

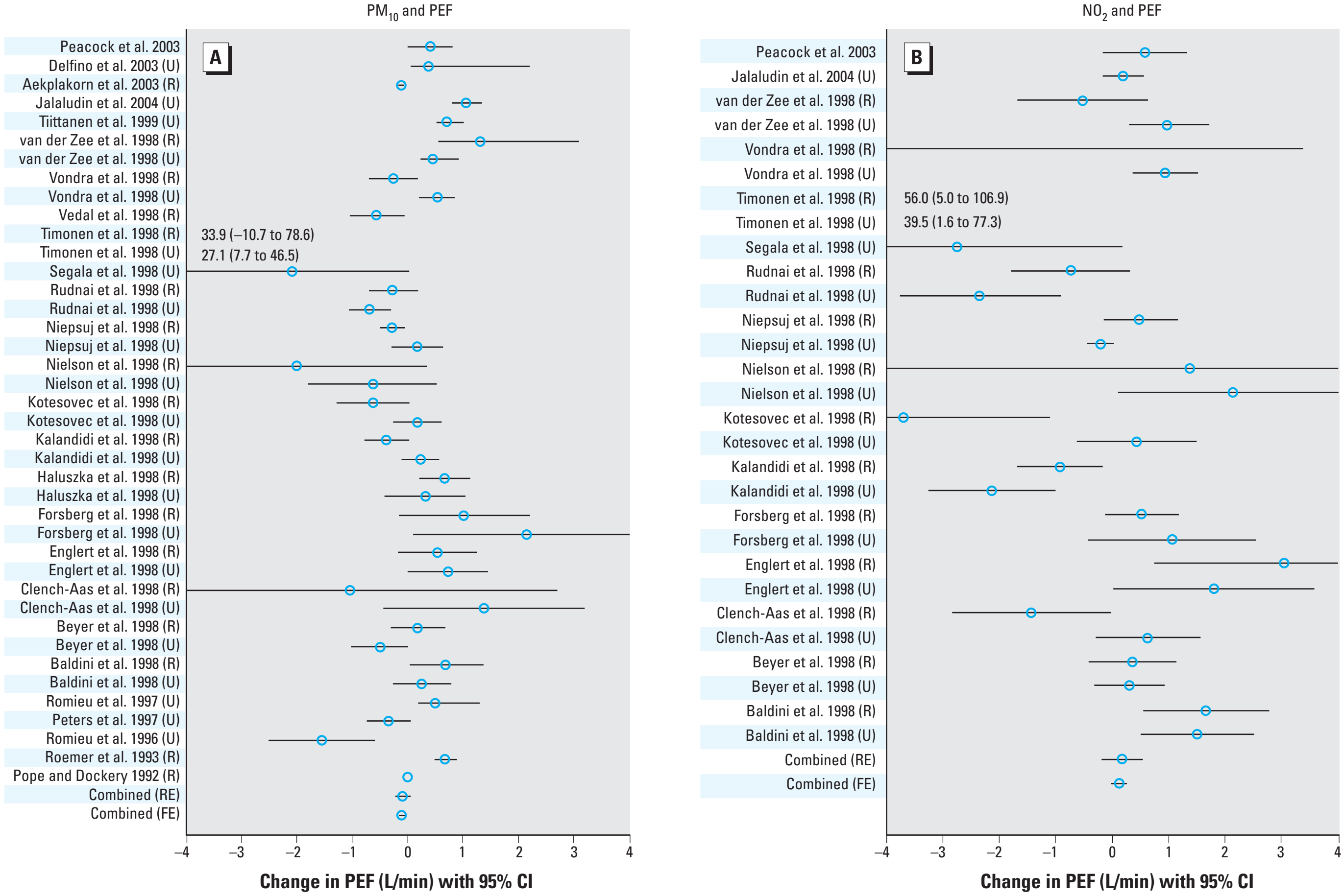

Figure 3. Mean increase in PEF (L/min) with 95% CIs for a rise of 10 µg/m^3 PM_{10} (*A*) or NO_2 (*B*). Abbreviations: FE, fixed effects; R, rural; RE, random effects; U, urban.

Table 2. Association of PM_{10} and NO_2 exposure with episodes of asthma symptoms, episodes of cough, and PEF in children symptomatic for or diagnosed with asthma.

	PM_{10}					NO_2				
Symptom	*n*	OR_F/β_F (95% CI)	OR_R/β_R (95% CI)	*p*-Value(I^2)	*p*-Value[a]	*n*	OR_F/β_F (95% CI)	OR_R/β_R (95% CI)	*p*-Value(I^2)	*p*-Value[a]
Asthma symptoms										
All studies	43	1.023 (1.013 to 1.034)	1.028 (1.006 to 1.051)	< 0.001 (59%)	0.779 (0.675)	34	1.026 (1.016 to 1.037)	1.031 (1.001 to 1.062)	< 0.001 (50%)	0.746 (0.594)
Without PEACE studies	17	1.035 (1.023 to 1.047)	1.055 (1.032 to 1.078)	0.002 (56%)	0.000 (0.053)	10	1.028 (1.017 to 1.039)	1.039 (1.018 to 1.061)	0.125 (35%)	0.001 (0.152)
Trim-and-fill estimate	24	1.028 (1.016 to 1.039)	1.035 (1.012 to 1.058)	< 0.0001 (61%)		15	1.026 (1.015 to 1.037)	1.032 (1.008 to 1.057)	0.052 (41%)	
Cough										
All studies	40	1.014 (1.008 to 1.019)	1.012 (0.997 to 1.026)	< 0.001 (69%)	0.442 (0.316)	30	1.006 (0.995 to 1.016)	0.987 (0.960 to 1.014)	< 0.001 (65%)	0.394 (0.158)
Without PEACE studies	14	1.020 (1.014 to 1.026)	1.035 (1.020 to 1.050)	< 0.001 (72%)	0.002 (0.07)	6	1.018 (1.006 to 1.030)	1.031 (1.005 to 1.057)	0.006 (69%)	0.007 (0.085)
Trim-and-fill estimate	19	1.018 (1.012 to 1.024)	1.027 (1.011 to 1.043)	< 0.001 (72%)		8	1.015 (1.003 to 1.026)	1.018 (0.988 to 1.050)	< 0.001 (76%)	
PEF[b]										
All studies	40	–0.117 (–0.160 to –0.073)	–0.082 (–0.214 to 0.050)	< 0.001 (72%)	0.456 (0.428)	29	0.130 (–0.008 to 0.268)	0.180 (–0.184 to 0.544)	< 0.001 (77%)	0.433 (0.925)
Without PEACE studies	12	–0.145 (–0.195 to –0.096)	–0.272 (–0.449 to –0.095)	< 0.001 (69%)	0.061 (0.451)	3	0.232 (–0.091 to 0.556)	0.170 (–0.590 to 0.929)	0.088 (59%)	0.594 (1.000)

Abbreviations: OR_F/β_F and OR_R/β_R, combined estimate of the OR (or regression coefficient β for PEF in L/min) from the fixed-effects and random-effects models, respectively, for a 10-µg/m^3 increase of pollutant; $p(I^2)$, *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.

[a] *p*-Value for Egger (Begg) bias test. [b] The metatrim command in STATA did not perform any trimming for this outcome ("no trimming performed, data unchanged").

particles PM (Seaton and Dennekamp 2003), remains to be investigated. The correlation between PM_{10} and NO_2 varies across settings (Katsouyanni et al. 2001), with the pollution mix related to NO_2 generally being more variable in space and time. Notwithstanding these differences, the estimated effect size for NO_2 observed in this meta-analysis is similar to that of the PM_{10} component, except for PEF.

There may be a concern that bias might be introduced when selecting effects that were not for the same lag. Our additional analysis for lags 0–1 provided nonsignificant estimates for NO_2 but significant associations with PM_{10}. It remains to be shown whether such a short lag is the most adequate for measuring the effect, given that higher associations may be observed at longer lags, as we found in our analysis of effect modification. Unfortunately, longer lags are less consistently reported in the literature.

Table 3. Stratum-specific combined estimates of the association of PM_{10} and NO_2 exposure with episodes of wheezing in children symptomatic for or diagnosed with asthma.

	PM_{10}						NO_2					
	All studies			PEACE studies excluded			All studies			PEACE studies excluded		
Stratum	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)
Continent			0.066			0.457			0.366			0.084
Europe	32	1.008 (0.975–1.043)	< 0.001 (60%)	6	1.069 (1.025–1.116)	0.121 (43%)	28	0.998 (0.942–1.058)	< 0.001 (56%)	4	1.085 (1.019–1.155)	0.126 (47%)
Other	11	1.050 (1.022–1.077)	0.006 (60%)	11	1.050 (1.022–1.077)	0.006 (59%)	6	1.025 (1.014–1.036)	0.471 (0%)	6	1.025 (1.014–1.036)	0.471 (0%)
Season			0.006			0.095			0.332			0.920
Summer only	5	1.090 (1.045–1.136)	0.682 (0%)	5	1.090 (1.045–1.136)	0.682 (0%)	3	1.057 (0.987–1.133)	0.166 (44%)	3	1.057 (0.987–1.133)	0.166 (44%)
Other	38	1.020 (0.997–1.043)	< 0.001 (60%)	12	1.046 (1.022–1.071)	0.003 (61%)	31	1.016 (0.974–1.059)	< 0.001 (52%)	7	1.053 (1.015–1.092)	0.112 (42%)
Population			0.029			0.963			0.132			0.434
Asthmatics	12	1.056 (1.025–1.088)	0.009 (56%)	12	1.056 (1.025–1.088)	0.009 (56%)	7	1.034 (1.011–1.059)	0.132 (39%)	7	1.034 (1.011–1.059)	0.132 (39%)
Symptomatics	31	1.007 (0.976–1.039)	< 0.001 (62%)	5	1.055 (1.023–1.088)	0.107 (47%)	27	0.986 (0.931–1.045)	< 0.001 (54%)	3	1.056 (1.010–1.104)	0.299 (17%)
Duration			0.758			0.645			0.285			0.192
≤ 2 months	14	1.022 (0.978–1.068)	0.001 (63%)	6	1.049 (1.013–1.087)	0.069 (51%)	10	0.954 (0.819–1.110)	0.003 (64%)	2	1.098 (1.009–1.194)	0.698 (0%)
> 2 months	29	1.031 (1.005–1.058)	< 0.001 (59%)	11	1.061 (1.029–1.094)	0.003 (62%)	24	1.037 (1.009–1.066)	0.011 (44%)	8	1.036 (1.014–1.057)	0.121 (39%)
Lag			0.325			0.438			0.601			0.597
≤ 2 days	22	1.020 (0.994–1.046)	< 0.001 (64%)	11	1.047 (1.020–1.076)	0.021 (53%)	16	1.016 (0.966–1.069)	0.002 (58%)	6	1.043 (1.004–1.084)	0.190 (33%)
> 2 days	21	1.044 (1.005–1.084)	0.012 (46%)	6	1.066 (1.028–1.106)	0.072 (51%)	18	1.037 (0.981–1.096)	0.020 (45%)	4	1.061 (1.009–1.115)	0.098 (52%)
PM_{10} level			0.102			0.795			0.079			0.612
< 40 µg/m³	19	1.057 (1.020–1.095)	0.053 (37%)	9	1.057 (1.034–1.079)	0.565 (0%)	16	1.062 (1.005–1.121)	0.064 (38%)	6	1.074 (1.029–1.121)	0.319 (15%)
≥ 40 µg/m³	23	1.016 (0.985–1.048)	< 0.001 (65%)	7	1.063 (1.021–1.106)	0.007 (66%)	17	0.982 (0.918–1.050)	0.001 (58%)	3	1.051 (0.976–1.131)	0.179 (42%)
NO_2 level			0.201			0.763			0.116			0.280
< 40 µg/m³	22	1.007 (0.966–1.051)	< 0.001 (59%)	5	1.059 (1.031–1.087)	0.586 (0%)	21	0.972 (0.894–1.056)	0.002 (54%)	4	1.095 (1.034–1.159)	0.798 (0%)
≥ 40 µg/m³	15	1.042 (1.010–1.076)	0.018 (49%)	8	1.051 (1.013–1.091)	0.038 (53%)	12	1.048 (1.002–1.097)	0.023 (50%)	5	1.053 (1.009–1.098)	0.100 (49%)
Rural/urban			0.261			0.289			0.559			0.052
Rural	18	1.008 (0.965–1.053)	< 0.001 (61%)	5	1.082 (1.022–1.145)	0.058 (56%)	14	0.997 (0.887–1.122)	0.008 (54%)	2	1.098 (1.033–1.167)	0.981 (0%)
Urban	25	1.038 (1.012–1.064)	< 0.001 (59%)	12	1.047 (1.023–1.071)	0.021 (51%)	20	1.033 (1.004–1.063)	0.007 (49%)	8	1.030 (1.012–1.049)	0.226 (25%)

Abbreviations: OR_R, combined estimate of the OR from the random effects model for 10-µg/m³ increase in pollutant; $p_{Strata}p_{het}$ (I^2), *p*-value for differences between strata and *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.

Table 4. Stratum-specific combined estimates of the association of PM_{10} exposure with change in PEF (L/min) and with cough episodes in children symptomatic for or diagnosed with asthma.

	PEF						Cough					
	All studies			PEACE studies excluded			All studies			PEACE studies excluded		
Stratum	*n*	β_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	β_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)	*n*	OR_R (95% CI)	p_{Strata} p_{het} (I^2)
Continent			0.041			0.750			0.001			0.047
Europe	33	0.002 (–0.182 to 0.186)	< 0.001 (72%)	5	–0.235 (–0.600 to 0.131)	0.006 (73%)	34	0.998 (0.983 to 1.014)	< 0.001 (62%)	8	1.020 (1.006 to 1.034)	0.026 (56%)
Other	7	–0.305 (–0.534 to –0.076)	0.003 (69%)	7	–0.305 (–0.534 to –0.076)	0.003 (69%)	6	1.053 (1.024 to 1.082)	0.004 (71%)	6	1.053 (1.024 to 1.082)	0.004 (71%)
Season									0.260			0.905
Summer only							2	1.039 (0.992 to 1.088)	0.602 (0%)	2	1.039 (0.992 to 1.088)	0.602 (0%)
Other	40	–0.082 (–0.214 to 0.050)	< 0.001 (72%)	12	–0.272 (–0.449 to –0.095)	< 0.001 (69%)	38	1.010 (0.996 to 1.025)	< 0.001 (70%)	12	1.035 (1.019 to 1.051)	< 0.001 (76%)
Population			0.007			0.086			0.001			0.217
Asthmatics	7	–0.549 (–0.920 to –0.177)	0.006 (67%)	7	–0.549 (–0.920 to –0.177)	0.006 (67%)	8	1.046 (1.022 to 1.071)	0.001 (70%)	8	1.046 (1.022 to 1.071)	0.001 (70%)
Symptomatics	33	0.010 (–0.159 to 0.180)	< 0.001 (73%)	5	–0.148 (–0.415 to 0.119)	0.002 (76%)	32	0.995 (0.978 to 1.013)	< 0.001 (63%)	6	1.026 (1.006 to 1.046)	0.005 (70%)
Duration			0.402			0.416			0.422			0.762
≤ 2 months	12	–0.161 (–0.394 to 0.071)	< 0.001 (67%)	4	–0.440 (–0.843 to –0.037)	0.010 (73%)	13	1.019 (0.995 to 1.043)	0.003 (59%)	5	1.034 (1.017 to 1.051)	0.188 (35%)
> 2 months	28	–0.032 (–0.225 to 0.160)	< 0.001 (74%)	8	–0.241 (–0.500 to 0.018)	0.079 (69%)	27	1.007 (0.990 to 1.026)	< 0.001 (70%)	9	1.038 (1.017 to 1.059)	< 0.001 (77%)
Lag			0.325			0.189			0.018			0.030
≤ 2 days	14	–0.167 (–0.354 to 0.021)	< 0.001 (70%)	8	–0.203 (–0.426 to 0.020)	0.001 (71%)	19	0.997 (0.979 to 1.014)	< 0.001 (74%)	6	1.022 (1.006 to 1.038)	0.004 (71%)
> 2 days	26	–0.025 (–0.237 to 0.187)	< 0.001 (73%)	4	–0.396 (–0.578 to –0.214)	0.392 (0%)	21	1.036 (1.009 to 1.065)	0.001 (56%)	8	1.067 (1.030 to 1.106)	0.001 (71%)
PM_{10} level			0.774			0.344			0.706			0.173
< 40 µg/m³	14	–0.021 (–0.441 to 0.398)	< 0.001 (68%)	4	–0.116 (–0.613 to 0.381)	0.006 (76%)	17	1.006 (0.983 to 1.029)	0.002 (57%)	7	1.022 (1.004 to 1.041)	0.047 (53%)
≥ 40 µg/m³	25	–0.086 (–0.233 to 0.061)	< 0.001 (74%)	7	–0.380 (–0.607 to –0.152)	0.005 (68%)	22	1.012 (0.991 to 1.033)	< 0.001 (74%)	6	1.045 (1.018 to 1.073)	< 0.001 (79%)
NO_2 level			0.722			0.028			0.012			0.031
< 40 µg/m³	21	–0.018 (–0.278 to 0.242)	68%*	3	0.144 (–0.224 to 0.512)	0.155 (46%)	20	0.980 (0.954 to 1.007)	< 0.001 (60%)	3	1.013 (1.001 to 1.025)	0.342 (7%)
≥ 40 µg/m³	11	–0.091 (–0.399 to 0.216)	80%*	3	–1.085 (–2.120 to –0.051)	0.028 (72%)	13	1.032 (1.001 to 1.064)	< 0.001 (72%)	6	1.065 (1.019 to 1.113)	< 0.001 (82%)
Rural/urban			0.911			0.433			0.116			0.604
Rural	18	–0.125 (–0.286 to 0.036)	< 0.001 (65%)	4	–0.301 (–0.507 to –0.096)	0.020 (70%)	17	0.994 (0.968 to 1.021)	< 0.001 (65%)	4	1.050 (0.995 to 1.109)	0.003 (79%)
Urban	21	–0.108 (–0.360 to 0.144)	< 0.001 (75%)	7	–0.473 (–0.851 to –0.095)	0.008 (66%)	23	1.020 (1.002 to 1.039)	< 0.001 (69%)	10	1.035 (1.017 to 1.052)	< 0.001 (70%)

Abbreviations: OR_R/β_R, combined estimate of the OR (or regression coefficient β for PEF in L/min) from the random effects model for a 10-µg/m³ increase in pollutant; $p_{Strata}p_{het}$ (I^2), *p*-value for differences between strata and *p*-value for test of heterogeneity based on Cochrane's *Q*, with I^2 of Higgins and Thompson reflecting the proportion of total variation in the estimate that is due to heterogeneity between studies.

*$p < 0.001$.

There are limitations of the panel studies we have considered. When evaluating symptoms, the possibility of a confounding role of medications should be considered. Medication use on polluted days may influence symptoms and lung function. Although the PEACE studies found no correlation between the number of children using asthma medication and air pollution levels (Roemer et al. 2000), this does not account for the possibility that asthmatic children increase the dose on such days. Information regarding this possibility is generally missing in the individual study reports. The evaluation of the effect on PEF is difficult because of the large between-individual variability of this indicator that is likely to be strongly influenced by medication use among diseased subjects. Finally, another difficulty is that the measured pollutants are only part of a more complex air pollution mixture, and the effects of "PM_{10}" and "NO_2" may vary among studies and may be a less or more adequate measure of the effects of air pollution. In a meta-analysis, it is not possible to adequately assess the problems related to these mixes. Multipollutant (mostly two-pollutant) models were calculated for only 10 of the study populations, and the combinations of the pollutants varied among studies. Only if the raw data were available for all studies could one attempt to tease out individual pollutant effects and also avoid overestimation of the individual effect. It will nonetheless be a daunting task, because in most cases criteria air pollutants are measured, which may be indicators of different unmeasured compounds in different areas. Delfino et al. (2003) reported, for example, that the effect of "PM_{10}" was lower when, for example, organic carbon, benzene, or *m*,*p*-xylene was included in two-pollutant models. This may be a general finding, or it may be typical for the region investigated. The results presented here therefore are not to be strictly understood as the effect of PM_{10} only or NO_2 only; the greater context must be borne in mind.

We observed a high degree of heterogeneity among the investigated studies. Stratifying by the identified effect modifiers reduced the heterogeneity only to some extent. We obtained the greatest reduction in heterogeneity when using the same lag for all studies. Sources of heterogeneity may be linked to various design aspects of the study, such as the inclusion criteria for the panel, duration of the study, and the analytical strategies. For the PEACE study with its standardized study protocol and common analytical strategy, we calculated an I^2 ranging from 40% to 79% depending on the outcome/pollutant only for the analysis using different lags, whereas the analyses with the uniform shorter lag reduced the heterogeneity among PEACE studies for symptoms and PEF (data not shown). Although this may highlight the importance of a standardized study protocol, caution is needed until it is better known which lag is the most appropriate. Therefore, other potential sources of the observed heterogeneity, such as differences in the air pollution mix related to spatial or temporal variability, may still be of importance even in well-standardized studies. Different baseline characteristics of the populations studied may also have their influence.

The estimated effect of PM_{10} on asthma was higher in studies that were conducted in the summer. The composition of the air pollution mix may also be the reason for higher observed effects of PM_{10} in studies that have been conducted in summer only. Summer pollution is qualitatively different from winter pollution: O_3 levels are higher, and in general the air pollution mixture is more strongly influenced by photochemical reaction. Ward and Ayres (2004) observed in their analysis a higher estimated effect in studies conducted in periods of high O_3 levels. A time-series analysis of Atkinson et al. (2001) observed effect modification by O_3 for hospital admission for respiratory conditions in persons older than 65 years, although not for asthma admissions in children or adults. Alternative reasons could be that the PM_{10} effect is confounded by the effect of O_3. However, independent effects have been found for $PM_{2.5}$, and for $PM_{2.5–10}$ concerning cough [for a more detailed discussion, see Ward and Ayres (2004)]. The higher estimated effect of PM_{10} in the summer could also be linked to more (active) time spent outside, which could act in several ways. First, it would reduce misclassification due to less exposure to indoor conditions. Second, it could increase the effect of PM_{10} through increased inhalation during the activities outside (e.g., exercise), which also could increase the effect of O_3.

Consideration of longer lags did result in elevated associations of PM_{10} with cough. This seems plausible because air pollution may act not only as a short-term trigger but also as a priming event by inducing processes of enhanced airways inflammation (Kimber 1998) that will build up over a period of hours to days and result in subsequent bronchial hyperreactivity (Mortimer et al. 2002). Indeed, lengthy lag periods have been found in panel studies as well as time-series studies of emergency department visits (Halonen et al. 2008; Mortimer et al. 2002).

Continent modified the association of PM_{10} with cough; we found a significant combined effect only for the studies outside of Europe, whereas for the European studies the combined effect was null (OR = 0.998; 95% CI, 0.983–1.014). This estimate is similar to that reported by Anderson et al. (2004) for Europe (OR = 0.999; 95% CI, 0.987–1.011). At first glance, a similar effect modification was present for asthma symptoms, but this disappeared after exclusion of the PEACE studies. It therefore remains speculative whether this is really an effect for Europe or is attributable to some other characteristic that is specifically related to the PEACE study.

Nevertheless, a stronger association of PM_{10} with respiratory symptoms reported in the United States compared with Europe was also observed in an earlier meta-analysis, conducted before the PEACE study, that also included healthy children (Dockery and Pope 1994). One plausible explanation could be different pollutant mixes on the two continents. The extent to which these differences are systematic and will provide relevant information remains to be investigated, given that also within the United States and within Europe there are marked differences concerning the air pollution mix, which may result in differing health effects via effect modification or due to a different composition of PM_{10} (Katsouyanni et al. 2001; Levy et al. 2000).

In our analysis, we found the association of PM_{10} with cough to be stronger for higher ambient NO_2 concentration. However, we did not see this effect in the analysis restricted to lags 0–1, but in this latter analysis we found higher associations at higher NO_2 levels with asthma symptoms. Effect modification by NO_2 has been found in time series studies on mortality in Europe (Katsouyanni et al. 2001), and to a lesser extent in the United States (Levy et al. 2000). It has been discussed that NO_2 is a marker for a certain air pollution mixture, notably arising from traffic, which is more noxious for health.

Conclusion

Our meta-analysis provides strong evidence for an effect of PM_{10} as an aggravating factor of asthma in children. Although there is no firm toxicologic evidence of adverse health effects of NO_2 at ambient levels to date, the epidemiologic results suggest an adverse effect of NO_2 on respiratory health in children with asthma. However, caution is needed in the final conclusion for NO_2 because the association with asthma attacks was not robust to lag specification. The finding may reflect the fact that NO_2 is associated at extended lags, or it may be only an artifact due to our method of choosing the specific lag to be included in the meta-analysis. More consistent reporting of longer lags is needed in panel studies to better judge the effect of monitored outdoor NO_2. The results of the study support the need to protect asthmatic children with strict air quality standards for PM_{10} and, considering the precautionary principle, also for NO_2.

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Dear Neighbor,

This plant will effect everyone in the neighbor and their outdoor activities. If you can't make the meeting, but want your position on the location of the plant known, you can send a note with me.

The note can be brought to 3014 Harper and left in the small box on the front porch.

All notes will be delivered to the ~~council~~ council.

A. Aron

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Put in sealed enevelop - deliver to 3014 Harper

For: [✓ Against:]

Name: Lindsey and Nicholas Trickey

Address: 3010 Harper St. Lawrence, KS

To the Lawrence City Commissioners,

Many topics and projects have come before the City Commission in the last 10 years that I have lived in Lawrence. I have stood back and watched as the City Commision has done nothing but make unintelligent, costly, conservative mistakes and decisions that are RARELY in the favor of the Lawrence population. The newest topic that has come to my attention has pushed me to the breaking point. This decision will not only affect my wife and myself, it will also affect my children. This, my questionable elected officials, is where I draw the line!

I live in a neighborhood that was built by the same company and family, the Salbs. They have created a wonderful neighborhood that is filled with families, just like my own. It sits on a quiet cul-de-sac and is a great, peaceful place for my neighbors and myself to raise our children and live our lives. Unfortunely, it does not come as a surprise that the city now has something in front of them that, again, could affect the Lawrence people around them. More specifically, the neighborhood that I have mentioned above. It has come to my attention that a new proposal has been brought to the table to build a "Temporary Concrete Batch and Storage Facility" within several hundred feet of this neighborhood and my home.

The concrete plant that is proposed, I understand, is a necessity to the needs of the new K10 project that is being built near 31st street. However, just because it is a necessity does not mean that it can just be thrown up anywhere with a disregard to the health and safety of the people around it. This plant is not just being built close to other buildings, it is being built next to single family homes with infants.and children! Concrete plants are responsible for toxic air pollutants, excessive noise, and health risk that can cause respiratory and cardiovascular disease, carcinoma (cancer) of the lung, stomach and colon, and potentially pneumoconiosis. Now ask yourself, would you want you or your family exposed to these kind of conditions? The answer, of course, is "No!" So why are you even considering the idea of allowing these conditions being allowed so close to mine?

I am hoping that the city can look and see the damages and dangers that this plant could potientially cause innocent bystanders and their homes and families. Being completely honest I am actually offended that the company would even consider building so close to a neighborhood and even more offended that the city is giving them the opportunity to do so! It basically says to me that money and convenience is more important than health and safety. There should be a law that prevents such plants or hazardous waste facilities from operating so close to residential neighborhoods. You know the right thing to do in this situation. Prove me wrong and make a decision that will actually benefit and protect the Lawrence people!

Sincerely,

A Concerned Lawrence Resident
2823 Harper
Lawrence, Ks
66046

Put in sealed enevelop - deliver to 3014 Harper
For:
Against: YES - I AM PUTTING
MY HOME UP FOR
SALE & DO NOT
WANT THIS TO
AFFECT ANY
POTENTIAL
SALE

Name: CHERYL SCHNETTLER
Address: 2830 HARPER ST

Put in sealed enevelop - deliver to 3014 Harper
For:
Against: X

Name: Shannon Herds
Address: 2926 Harper St
Lawrence KS 66046

Put in sealed enevelop - deliver to 3014 Harper
For:
Against: ✓

Name: Daniel & Sarah Ouellet
Address: 2823 HARPER

Dear Neighbor,

This plant will effect everyone in the neighbor and their outdoor activities. If you can't make the meeting, but want your position on the location of the plant known, you can send a note with me.

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All notes will be delivered to the ~~council~~ council.

A. Aron

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Put in sealed enevelop - deliver to 3014 Harper

For: [✓ Against:]

Name: Stephen + Janet Garlow
Address: 2808 HARPER St

Please attend the Douglas County Board of County Commissioners Meeting on Wednesday, March ~~19~~ 26,
~~6~~:30PM at the Douglas County Courthouse
4:30

Dear Neighbors,

As part of the construction plan for the completion of the South Lawrence Trafficway and extension of 31st street to O'Connell, the builder plans to erect a Concrete Batch Plant and Storage facility to be located directly south of the Salb-Mary's Lake Development.

Concrete Batch and Storage facilities create:

Toxic and Hazardous Air Pollutants

Carbon/nitrogen/sulphur oxides, Organics, Phenol, Polycyclic aromatic hydrocarbons (PAHs), Benzene, Formaldehyde, Acetaldehyde, Toluene

Particulate Pollution

Dust –lime content can be damaging to structures

Noise Pollution

Health Effects: Increased risk of respiratory and cardiovascular diseases, Cancer

The builder is seeking a **32 month** permit to build and operate the cement plant. This type of facility so close to our homes would not only endanger our health but also our property and our environment.

This permit will be discussed at the Douglas County Board of County Commissioner's Meeting on Wednesday, March ~~19th~~, ~~6:30~~PM 26 at 4:00
Douglas County Courthouse, 1100 Mass.
Please consider attending to let your voice be heard.

For more information or discussion please feel free to contact Daniel and Kristin Aillon
785-760-4643 or aillon@mac.com

DOUGLAS COUNTY ZONING & CODES DEPARTMENT
2108 W 27th Street, Suite I
Lawrence, Ks 66047
Phone: 785.331.1343 Fax: 785.331.1347

NOTICE OF PUBLIC HEARING

TO : Property owners within 1,000 and 200 feet of a Temporary Business Permit
Situs Address: 1535 N 1300 Road, Lawrence, KS 66046
Applicant: Landplan Engineering for Emery Sapp & Sons, Inc.
Owner: Kansas Department of Transportation

FROM: Linda M. Finger, Interim Director of Zoning & Codes Department

RE : Proposed Use – **Temporary Concrete Batch Plant and Storage**

DATE : February 27, 2014

This letter is sent to inform you that this office has received an application from Emery Sapp & Sons, Inc. for a Temporary Business Permit. The purpose of the Temporary Business Permit is for a temporary concrete batch plant and storage at 1535 N 1300 Road, Lawrence, Kansas.

If this item is of interest to you, it will be on the Douglas County Board of County Commissioner's Agenda on March 19, 2014. The time of this meeting will be 6:30 P.M., on the 2nd floor of the Douglas County Courthouse, 1100 Massachusetts Street, Lawrence, Kansas 66044.

Should you have any questions or comments concerning this request, please feel free to contact our office, the applicant directly, or a County Commissioner. You may also attend the meeting on March 19, 2014 and speak to the County Commissioners directly. You may contact me at the Douglas County Zoning and Codes Department at (785) 331-1343.