# Minimizing Dust in Low Rise Housing Design through Surface: A Literature Review

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***Abstract*—The existence of dust in a building environment can cause many problems for those who continually exposed, especially for residential housing which is located near the industrial area. There are so many kinds of dust included PM10 in which it can make upper respiratory tract infection. So, it needs a treatment process for reducing the dust intensity, one of the ways is through exploring the surface. In this paper highlighted about literature review for knowing the element surfaces that related to the way for reducing dust. Therefore, in this stage is needed for searching the surface elements that can be used in the next design process. The result of this review is the selection of building shape can help in controlling dust spread such as in courtyard typology. After that, it should consider with tilt angle of the surface in order to dust cannot be trapped and the position of surface from the direction of wind. The surface should have a minimum opening regarding to standard so that the view should face to the area where is not exposed by dust and air exchange can use shaft ventilation or hidden gap in the wall for helping to air flow.**

***Keywords*—Airflow, Dust, Literature Review, Low rise housing Design, Surface.**

## I. INTRODUCTION

THE residential design needs some considerations regarding to site location for instance the context analysis. In this case, the design is located near the highway of industrial area where it contains high level of pollution, one of them is dust. So that, the main reason why it's important to minimize the dust in a residential building for instance low rise housing is to avoid the sick building syndrome (SBS) to those who continually exposed. Symptoms that can be indicated as a characteristic of sick building syndrome are headaches, dizziness, nausea, eye irritation, nose, throat, allergies, asthma, shortness of breath, and personality changes [1][2]. Dust is small solid particles carried by airflows measuring 1 to 400 microns that originate from manufacturing, industrial, construction, agricultural, etc. [3]. In addition, dust is used as an indicator of air pollution to show the level of danger posed to the environment and health [4]. This is because the character of dust itself can trigger allergenic symptoms, dizziness and reduced concentration in humans [5] and shortness of breath [2]. In addition, dust can also cause aesthetic disturbances in building materials, damage plant life due to the closure of pores that disrupt photosynthesis, change regional and international climate, and disrupt flights [4][6].

The dust itself consists from respirable dust that is sized 1-10μm, inhalable dust that sized 10 μm, and total dust includes all particles in the air [3] and the spread of dust is strongly influenced by the presence of airflow or the wind that carries it [7][8]. Airflow is the movement of air from one place to another. This becomes an important thing in the process of designing buildings that respond to dust from the outside environment. This is because airflow has a speed that can affect the spread of dust in the building [7]. In principle, the higher the speed of airflow, the more dust particles will be carried away [9]. According to Beaufort, an inventor of the scale of wind power, dust can be carried by the wind with a minimum strength of 5.5 m / s [10]. Airflow is the media or energy that causes dust to move from one place to another. The higher the air velocity, the more dust particles will be carried away [9].

In the last previous research, control of the spread of dust is basically the principle of prevention by reducing the formation and spread of dust, creating a dust collection system, or isolation of occupants from exposure to hazards through a closed space system that has clean and fresh air [3]. However, in building these basic principles can be done with the following applications [1]:

a) The HVAC system is designed according to ventilation standards in local building codes. The regulation of air exchange in buildings through ventilation can improve air quality in the room. There are two types of ventilation, namely natural, which is influenced by wind and mechanical ventilation which works through mechanical equipment. Natural ventilation consists of several types such as single ventilation where air comes from an open, cross where air flows from one place to another crossing, and stack where there is an influence of heat pressure in the room which causes air to rise upwards [11]. Whereas mechanical ventilation works using a fan and ducting system to drain air from the outside in and requires large energy with a complex system [11].
b) Regular treatment of the HVAC system and material that causes sick building syndrome.
c) Cleansing air and plants as a control of dust. The characteristics of plants that can be used as air pollution control is fast growth and can grow anywhere, able to withstand water pressure and extreme climate afterwards, and able to improve atmosphere condition [12].
d) Good management in the dust control system.
e) Rules for limiting smoking.
f) Location of residential buildings far from industrial centers or major traffic routes.
g) Setting the composition of the layout will also affect the direction of the wind entering the building [13]. For example, an open plan such as an auditorium has the potential for the spread of dust that comes in compared to space layouts that have multiple partitions which make it difficult to spread the dust.

Table 1.
Comparison between Building Shape, Airflow, and possibility of Dust Spread

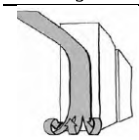
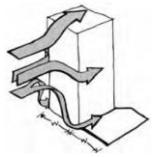
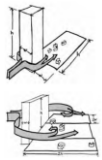
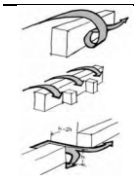
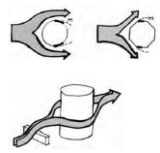
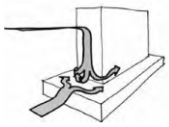
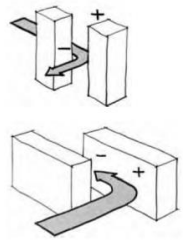
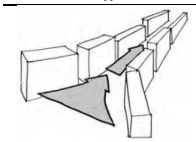
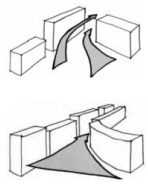
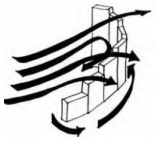
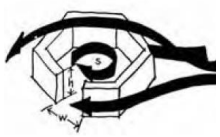
| Building Shape | Airflow | Dust Spread Analysis | Reference |
|---|---|---|---|
| *Rectangular tower and slab blocks* | | | |
|  | Downwash is a phenomenon that is occured due to the increasing difference in wind pressure in a building. Simple square-shaped buildings have a strong wind zone on the base area. | The dust will be concentrated below due to downwash effect that make lower side of the surface shows higher concentration | [14][15] |
| Corner effect | | | |
|  | Corner effect occurs because the concentration of air in the area of the building will flow quickly to the corner area of the building towards the back side. | The dust will have possibility to concentrate below or stick in front of surface or flow quickly follows the wind | [7][14] |
| Wake effect | | | |
|  | Wake effect occurs due to an increase in wind speed and turbulence in the area behind the arrival of wind flow direction due to separated airflow. | The dust will spread into back of surface due to the turbulence phenomen | [7][14] |
| Cumulative effect | | | |
|  | Cumulative effect is the effect that occurs in a group of buildings. | The height of the building is able to bend the wind direction due to turbulence so that suddenly a clean surface can become dirty . the density of building also influence the wind direction | [7][14][16] |
| *Low bar building (row effect)* | | | |
|  | The wind will actually pass through the facade of this elongated building. The method used to reduce the effect of wind flow on elongated buildings is to add a few wings to the main block. | The dust will spread into back of building shape due to row effect and turbulence phenomena | [7][14] |
| *Cylinder shape* | | | |
|  | Cylinder-shaped buildings will tend to continue the downward rate and cause inconvenience to the occupants of the tower due to the relatively large wind speed. | The dust will be carried away by airflow. In one side, dust can't easy to stuck but the other side the high speed of wind can spread the dust quickly into another side. | [7][14][17] |
| *Tower Podium* | | | |
|  | The shape of the podium is the most ideal design to provide comfort to residents in buildings and the surrounding environment because the direction of wind flow tends to be on the lower side of the tower. | The dust will be concentrate above the podium due to downwash effect but wind tend to flow above the podium roof so that it can help for cleaning the dust. | [14] |
| *Pyramid Effect* | | | |
|  | Pyramid effect can reduce wind flow in the basic area of the building but on the other side of the balcony area will tend to be disturbed by the distribution of the wind flow. | The dust will concentrate in each pyramid floor because the reducing of wind flow which make dust can't easy to clean. | [14] |

Table 1. (Continued)
Comparison between Building Shape, Airflow, and possibility of Dust Spread

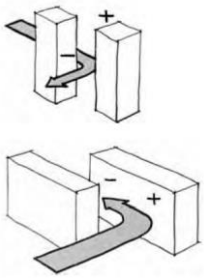
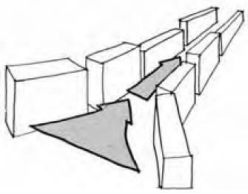
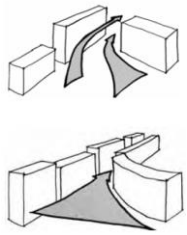
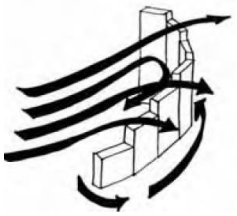
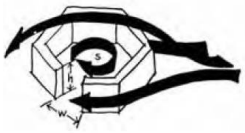
| | | | |
|---|---|---|---|
| *Low and high building* | | | |
| | Wind speeds will increase between the sides of low buildings with tall buildings. This is due to the downwash effect on the building. | The dust will concentrate in the gap between low and high building because it is trapped here. | [14][15] |
| *Staggered building* | | | |
|  | Buildings that are close together can protect each other from strong winds or even make things worse because of differences in wind pressure resulting in winds moving from high to low pressure. | | |
| *Channel effect* | | | |
|  | Rows of parallel buildings will form a corridor that can cause comfort if the wind conditions are good or even create discomfort when there are bad wind conditions. | | |
| *Funneling effect* | | | |
|  | An adverse funnel effect occurs when the width of the openings is two or three times the average height because it will accelerate the flow of wind in the funnel area due to the venturi effect. | | |
| *Stepping effect* | | | |
|  | Stepping effect will occur in a group of buildings with high differences due to differences in pressure in several zones. | | |
| *Courtyard effect* | | | |
|  | Winds will tend to above buildings or just pass on the courtyard. Factors that influence the amount of wind passing on the courtyard are influenced by the height of the mass, the width of the courtyard, and the openings. | | |

Dust itself can be indicated in surface. This is caused by the most effective indicator to find out the intensity of dust is through surface [18]. Therefore, surface exploration is needed as a guide, filter, or trapper from the presence of dust carried from the outside environment into the building. In low rise housing typology, the surface is rarely a flat planar surface, this needs to be reviewed so as to know the right kind of surface through several theories related to wind, surface, and low-rise housing typology. Surface itself is an extension of a line into one that has length, width, appearance, surface, orientation, and position. Surfaces are 2-dimensional form elements of a form. Furthermore, the extension of a surface becomes one that has length, width, depth, shape, space, surface, orientation, position is a volume that is in the form of 3 dimensions [19]. So that, the novelty of this research is for knowing the surface shape that can minimize dust effectively in low-rise housing building type which can be used in the next design process.

## II. METHOD

The method which is used is literature review [20] through comparison of several related theories from book, journal, or standard. This method is used to know about the element of building surface which influence the dust spread especially in low-rise housing building.

Table 1. (Continued)
Comparison between Building Shape, Airflow, and possibility of Dust Spread

| | | | |
|---|---|---|---|
| ***Staggered building*** | | | |
|  | Buildings that are close together can protect each other from strong winds or even make things worse because of differences in wind pressure resulting in winds moving from high to low pressure. | Dust will be move follow the changes of wind direction. | [7][14] |
| ***Channel effect*** | | | |
|  | Rows of parallel buildings will form a corridor that can cause comfort if the wind conditions are good or even create discomfort when there are bad wind conditions. | Dust spread will be follow the wind direction. | [7][14] |
| ***Funneling effect*** | | | |
|  | An adverse funnel effect occurs when the width of the openings is two or three times the average height because it will accelerate the flow of wind in the funnel area due to the venture effect. | Dust will quickly spread because the venture effect. | [14] |
| ***Stepping effect*** | | | |
|  | Stepping effect will occur in a group of buildings with high differences due to differences in pressure in several zones. | The difference of height of the building is able to bend the wind direction due to turbulence so that suddenly a clean surface can become dirty. | [7][14] |
| ***Courtyard effect*** | | | |
|  | Winds will tend to above buildings or just pass on the courtyard. Factors that influence the amount of wind passing on the courtyard are influenced by the height of the mass, the width of the courtyard, and the openings. | Dust spread will be trapped in outer wall and difficulty to enter the indoor building area because wind tend to flow above the building | [14] |
| ***Low and high building*** | | | |
|  | Wind speeds will increase between the sides of low buildings with tall buildings. This is due to the downwash effect on the building. | The dust will concentrate in the gap between low and high building because it is trapped here. | [14][15] |

## III. RESULTS AND DISCUSSION

The discussion is needed to review the correlation of building shape and dust spread analysis and to know about the typical surface shape in low-rise housing which can clean the dust easier. First, building shape is consisted of various types, so that needed to know how airflow responds around the building shape to ensure the dust exposure as described in Table 1. In high pressure of wind, dust has the possibility to stuck but it also depends on wind speed and the surface condition either shape or material. Second, the low-rise housing typology surface, usually has a requirement for shading and view so that it should be fulfilled before and has a consequence that influence the dust spread as defined in Table 2. In that table is also discussing about the several of surface either planar, tilt, curve, or cavity shape with the response to the dust spread. Then, material, overhang, and wall window ratio are also noticed because all of them are part of facade component in the design. For clearly understanding, in Figure 1 is talking about the connection between theory and design aspect in which surface will be implemented in building shape so that the selection of building shape will be a crucial point because it will help for controlling of dust spread. Then, the selection of surface will be applied in façade that relates to overhang, wall, and wall window ratio, but in other side low rise housing also needs a view, airflow exchange, and shading. All of the components will have

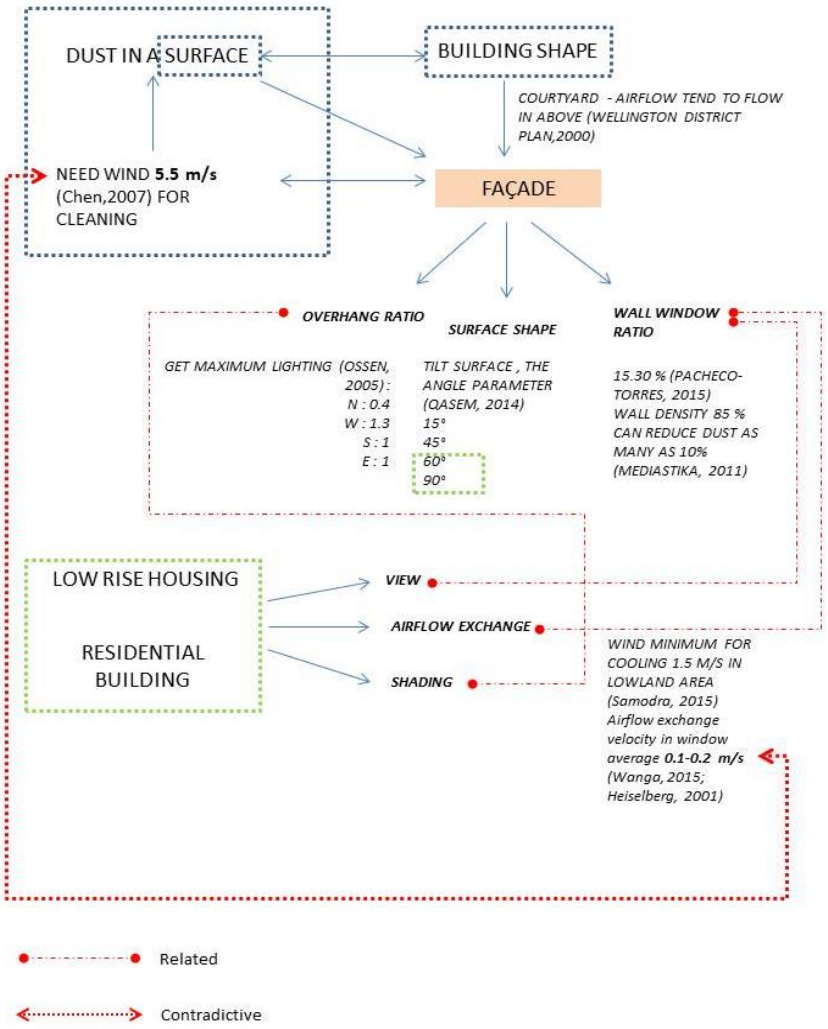



Figure 1. Scheme of Design Aspect for Reducing Dust.

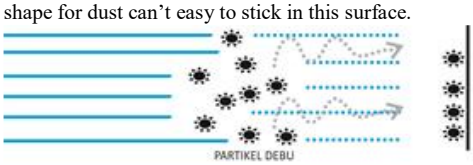
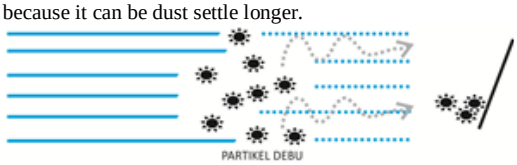
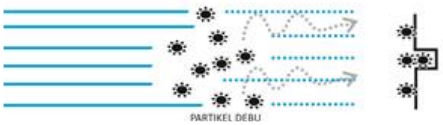
a correlation each other both in façade and building aspects, but unfortunately wind requirement will make a contradictive because of air exchange it needs 0.1-0.2 m/s but for cleaning the dust it needs 5.5 m/s [19][21], and [22] so that it will make a consequence it the selection of building shape and surface for fulfilling those matters.

Based on this review, the courtyard type has possibility for controlling dust spread from outdoor to indoor because the airflow will tend to flow above the building and courtyard can isolate the occupants from dust exposure from outdoor [3][14]. In façade element, the view and air exchange will be limited because the WWR criteria for reducing dust only 15 % and the wind velocity in outdoor surface is 5.5 m/s. Thus, it will influence room inside the building and of course in a whole design. The most important is the selected surface both of shape and material because it will make dust can easy to move or thick here.

From Table 1, all building shapes will give a different response to dust spreads depend on the wind effect that occurred on the surface. Wind effect which happened to make the dust move from surface or even make a clean surface change in dirty conditions. So that, it is important to select the right of building shape for helping in controlling the dust spread in a building. From all of the dust spread analysis in the building, a courtyard effect is an ideal option to be selected because it can make the dust stay on outside the building and small chance to enter the building since wind tends to flow above the building. The consequence which occurs in the surface is a minimum opening and treatment for air exchange, for instance through shaft ventilation in each unit or hidden gap in the wall. Furthermore, the surfaces also influence the façade component such as overhang for shading devices to avoid the sun radiation [23]. In Figure 1 describes the correlation in between the surface, building shape, façade and low rise building itself, in which there are some aspects that relates but there is one aspect which contras as described before so that the next design should adjust this matter about the wind requirement that is needed for air exchange and for cleaning the dust.

The surface shape analysis is needed to know about how the dust will respond to the various surfaces. From Table 2, it can be concluded that dust will trap in the cavity surface because the wind can not to enter and clean the dust in surface. The other shapes such as planar and tilt is a good choice but should notice with the slope angle. For curve, it is also good, but it can make the dust spread be uncontrolled. Then, surface also relates to material, overhang, and WWR. In material, dust can disturb the aesthetic so it should consider with the color selection or treatment that makes dust can erase easily. In overhang should relate to slope of angle in order that dust cannot be trapped here. Then, in WWR should have very maximum of opening that would be allowed.

Table 2
Surface Analysis

| Item | Dust Spread Analysis | Reference |
|---|---|---|
| Surface Shape | | |
| Planar | Regarding wind flow effect dust will be concentrated in lower side. Planar side has 90° angle from horizontal side that make it's a best shape for dust can't easy to stick in this surface.   | [7][14][24] |
| Tilt | Tilt angle make the dust tends to fail to stick in a surface because it does not have symmetry of surface contour. The specific angle that can be selected is 15°, 45°, 60°, 90° and avoid 0o and 30o because it can be dust settle longer.   | [24][25] |
| Curve | Curve shape make the dust can't easy to stick in surface because it has momentum changes due to first Newton Law but curve also make dust can spread and move quickly in outdoor area uncontrolled because the improvement of wind. So that it also make uncomforted feel to the residents inside.   | [14][17] |
| Cavity | The shape with gap or cavity usually makes the dust is stuck inside because can't easy to move and high pressure in there so that it will be attention in order to dust can move.   | [15] |
| Material | Material can make the dust settle in surface or not. Rough material will make dust trapped but fine material will make dust easy to clean. The chemical reactive compound will help surface have the quality of self-cleaning. The combination from both of them is needed because rough material will help for trapping the dust and fine material will help for cleaning. Vegetation material might be able to be selected for trapping the dust in the wall. | [9][12][26] |
| Facade Overhang | Overhang is needed for shading in the building. Herewith the shading ratio for optimum lighting :<br>N : 0.4<br>E : 1<br>W : 1.3<br>S :1<br>The shading might be can catch the dust so that need to improve the shape in order to dust can easy to clean | [7][14][15][24] |
| WWR | Windows wall ratio is needed for view and air exchange but it should be consider with the capability for reducing dust so that need to aware how many percentage the opening that is allowed. In this case, is maximum 15 %. | [27][28] |

## III. CONCLUSION

The conclusions from those theories results the general criteria of design for instance:

1. The outdoor airflow will influence the dust spread in the building. So, the design needs the right typology of building that can be a control for dust spread through analysis of wind to building. From the analysis, courtyard will help in controlling dust spread because the dust will trap in outdoor wall or above the building through wind flow. So

that, the composition of surface is needed for helping dust to move in the building shape.

2. The design should consider with a view, airflow exchange, and shading because of residential building. So that, the design for reducing dust should adjust those matters before, for instance view directed to an area which not exposed by dust, indoor airflow requirement can get inside the courtyard or other treatments like shaft ventilation or hidden gap in the wall, and shading should consider with the angle tilt direction.
3. The shape of surface will influence the dust spread. So that, it is needed the combination of several aspect to treatment the dust for instance the right of tilt angle, material, overhang, and WWR.

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