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RISK ASSESSMENT OF ACCIDENTAL FIRE BREAKDOWN: A STUDY ON AN URBAN AREA, KHULNA CITY CORPORATION

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ABSTRACT

The aim of the project is to determine the risk of fire hazard in a specific portion of Khalishpur area, Khulna. The residential areas close to the three oil depots and two power stations are considered to be the most vulnerable and the deliverable of this project is to assess the risk of these settlements at different distances from the risky land-uses. At present, the number of accidents due to fire are rising year to year at a very ascending rate which is a huge threat for the urban environment. Not only in Bangladesh but fire hazard is now a concern for all the nations across the globe. According to the World Disaster Report, about 1 billion people are residents of urban area over the world and are yet the most vulnerable towards disasters as cyclones, earthquakes, fire, flood, crime, industrial accidents and many more. Considering the fact that maintaining land use zonal variance is completely absent in Ward no. 07 of Khulna City Corporation, is the selected areas for conducting the study. The study area is of 0.404sq. km, having a population of 18,000.To determine the risk of the residents of the area, a sample size of 20 households were taken and then for primary data source questionnaire for the local residents were prepared including the factors to be considered to assess the risk. After that the field survey was conducted for data collection and also consulted some local political influencers for more supporting data. Also distance from the depot, distance from the power station, distance from the hospital and fire service station these data were collected by field survey. Other secondary data such as population, ward boundary area were collected from website of KCC and some from BBS. To analyze the data to get the expected outcome AHP method was used. Five sub factors considered for hazard were distance from depot, smoker by habit, electric connection status, cooking system and distance from power station. Six sub factors considered for vulnerability were Building type, surrounding land-use, Fire station distance, hospital, Building Storied and Fire Management System. And for Elements of risk 4 sub factors considered are population size, population distribution, health condition and monetary property value. Using the AHP method the weightage to the sub components were identified. And finally using the Risk Function, the risk status of the 20 sample buildings was determined. It is found that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at an extreme risky condition. After assessing the risk of the buildings the coordinates of the building were used to point those out in the map produced using ArcGIS 10.5. There will be 3 risk levels (Low, Moderate and High) for the building and will be displayed by 3 different shapes. Finally a map was generated showing the position of the buildings and its risk statues using different points of different shape on the map.

Keywords: *Accidental fire breakdown, Land use zonal variances, Analytical hierarchy process and focus group discussion.*

1. INTRODUCTION

At this edge of 21st century, urbanization has accelerated to such a rapid pace. About 1 billion people are residents of urban area over the world and are yet the most vulnerable towards disasters as cyclones, earthquakes, fire, flood, crime, industrial accidents and many more (Disaster Report 2013, 2014). According to the world disaster report, 2010, flood, earthquakes, cyclones are categorized as urban disaster whereas fire hazard or explosions are more of a technological hazard (International Federation of Red Cross and Red Crescent Societies, 2016). Talking about Bangladesh, in recent years Bangladesh has faced several massive fire and explosion hazards and has very poor management quality to meet the necessary qualification to prevent the hazards. A statistics state that on an average 53 fire accidents were occured daily in Bangladesh in the year 2018 (Hossain, 2019). Among the cities of Bangladesh, Dhaka faced 2334, Chittagong faced 1735 and Khulna faced 1041 occurrences in the same year (Disaster Report 2013, 2014). In a study it is found that most of the accidental firebreakdowns arise in Bangladesh due to unplanned development of urban areas, lack of fire management system and the amount of losses heightened because of ineffectiveness of mitigation measurs like narrow roads, absence or narrow emergency exits point, inadequate number of fire stations etc (Islam & Hossain, 2018). An accident was triggered by the explosion of electric tranformer and was then fanned due to thr explosive liquids that are stored nearby in in the Nimtali area of Old Dhaka in 2010. This incident was named as Nimtali Tragedy and results in the death of 117 local residents and injury of more than 100 people (Imam, 2010).

Oil depots are the store house to a lot of flammable petroleum products. By chance the fuel and air comes in contact or stored fuel gets ignited somehow there is a high possibility that in may turn to a huge fire explosion. Also while regular maintenance like cleaning or nearby activities like cooking, welding, industries etc. these might be a reason to accidentally trigger a fire explosion causing great casualties, heavy environmental pollution and massive economic losses as well. . For the past few years, a series of large fire and explosion accidents were happened in oil depots all the world around, such as the Buncefield oil depot explosion in London (Zhou et al., 2016). In December 2005 an accident was occur in Buncefield, 40 km northwest of London, which caused a drastic disruption in the environment as well as in the economy. This accident cause resettlement of about 2000 people, reconstruction of about 29 km of road, relocation of nearby businesses, pollution of groundwater and many other environmental impacts (Atkinson, 2014).

Khulna City being the heart of the south-western part of the country and due to the recent communication development with the south west, rapid pace in urbanization in Khulna city is being seen in recent years. Therefore, the risk of fire hazard is increasing day by day. The way to reduce such risk is to assess the vulnerability of areas with heavy industries, oil depots, densely populated areas etc. In this study, Analytical Hierarchy Process (AHP) is used to weight the factors considered responsible to trigger a fire hazard and Geographic Information System (GIS) is used to overlay those and generate a map showing the radius of area under risk due to the presence of the fire risk factor.The Analytic Hierarchy Process (AHP) is widely used by decision makers and researchers. The definition of criteria and the calculation of their weight are central in this method to assess the alternatives. However, there are few studies that focus on them (FSM Russo & Camanho, 2015).
This study is conducted in Khalishpur, Khulna as there are presence of oil depots and also residential and commercial mixed land-use at a very low distance making them the most vulnerable group. As a whole the study is conducted to determine the risk under which currently the residents of ward no. 07 and 08 are in due to not maintaining the land use zonal variance and still growing residence beside such a risky land use zone.

2. METHODOLOGY

The project focuses at risk assessment for fire hazard in word no 7. At first the risk function was studied and then the sub factors and element under the main factors were fixed.

2.1 Study Area

At a present scenario Khulna is the third largest city in Bangladesh and one of the largest economic hub of the country, therefore fire hazard assessment to be able take necessary measures is un avoidably important. Khulna has faced a total of 190 massive fire incidents from years 2014-2017. In 2014 there were 29 incidents. In 2015 it was 27, in 2016 it was 67 and in 2017 it was 69, which shows the fire hazard is occurrence rate is increasing at an alarming rate (Bangladesh Fire Service and Civil Defense Authority, 2018). Due to mixed and unplanned land-use, the study area selected is Ward no 7 of Khulna city, having 3 massive oil depots and 1 power station just adjacent to residential area. A 225MW power station close to an oil depot, a simple shot circuit fire will be able to create a massive disaster.The study area is of 0.404sq. Km (Source: Khulna City Corporation), having a population of 18,000 (Bangladesh Bureau of Statistics, 2001).Figure:1 represents the map of the study area.

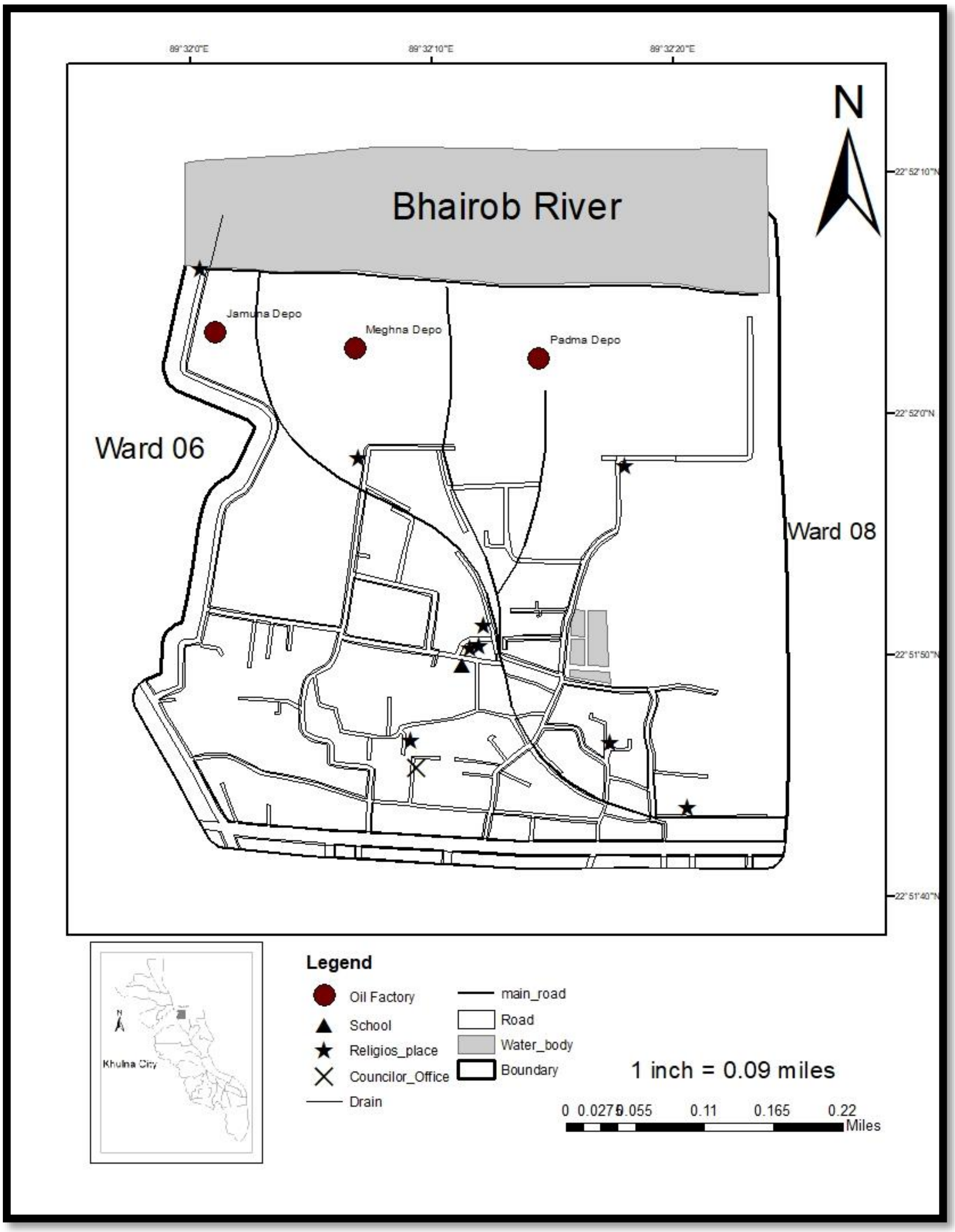

Figure 1: Landuse Map of the Study Area

(Source: Author, 2019)

2.2 Study Design

For data collection primary/ field survey was the main process of data collection. In field data collection two parts were performed

- Questionnaire survey and focus group discussion
- GPS coordinate marking.

Questionnaire survey was prformed at 20 building of different land uses. The local residents were asked about the factors about fire hazard as well as warned to be cautious.Also secondary data were collected from KCC and the population from BBS. The local councilor were interviewed as key in formant. These are the secondary data sources.

The analysis of the collected data are performed in two steps to finally display the output in a map. The main process to be followed, to determine the weightage and in this is were AHP is used to assess risk.

In this case AHP method is used for weighing the factors. Pairwise comparisons are made between the components as well as between the sub-components and the relative importance between each pair of decision alternatives and criteria is rated. Normalization Pair wise comparison matrix are then calculated for the components and each of the sub-components.

$$\text{Normalize Value} = \frac{\text{Column Value of Pairwise Matrix}}{\text{Column Sum of Pairwise Matrix}}$$

From those matrix criteria of the components and sub-components are calculated by using the given formula.

$$\text{Criteria Weight} = \frac{\text{Rowsum of Normalize Matrix}}{\text{No. of Component}}$$

The final step is consistency check to determine the consistency of the calculated weight (FSM Russo & Camanho, 2015).

After the determination of risk status of the buildings, with the help of ArcGIS 10.5 the buildings will be pointed out with points on the map. According to the risk status the color code for the determination of buildings at the highest and lowest possibilities.

3. ANALYSIS AND FINDINGS

Land use Zonal Variance is a major concern especially for risky land-uses adjacent to other regular land-uses. The study area consisting of 3 oil depots which stores massive amount of petroleum and also manual handling within the study area increases the risk of hazard. On the other hand the power points located right next to the petroleum depots are on 225MW capacity which adds to the risk to trigger an explosion.

3.1 Hazard Index

Five components are selected for hazard index.

- Distance from depot
- Smoker by habit
- Electric connection status
- Cooking system
- Distance from power station.

Sub-components of status of electric connection are legal connection and illegal connection and the sub-components of cooking system are electric cooker, Stove, LPG and pyre. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. Table 1 shows the weight of each components and sub-components.

Table 1: Weights of Component and sub-component of hazard index

Component	**Sub-component**	**Weight**	
		Sub-component	**Component**
Distance from Depot	0-0.375	0.1	0.421
	0.376-0.75	0.2	
	0.751-1.125	0.3	
	1.125-1.5	0.4	
Distance from power station	0-0.5	0.1	0.244
	0.51-1	0.2	
	1.01-1.5	0.3	
	1.51-2	0.4	
Cooking System	Stove	0.095	0.080
	LPG	0.307	
	Electric Cooker	0.040	
	Pyre	0.557	
No. of Smoker	1	0.3	0.044
	2 or more	0.7	
Electrical Connection	Legal Connection	0.3	0.211
	Illegal Connection	0.7	

Source: Author, 2019

Finally the hazard index of a building is calculated by using the given formula.

$$\text{Hazard Index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the fire hazard index is classified into three categories, low (0.140-0.220), medium (0.220-0.300) and high (0.301-0.380). According to this classification, 25% buildings are at low level, 35% are at medium level and 40% are at highly hazardous.

3.2 Vulnerability Index

Six components are selected for vulnerability index.

- Building type,
- Surrounding land-use,
- Fire station distance,
- Distance of hospital,
- Building storied
- Fire Management System.

Sub-components of building type are “pucca”, “semi-pucca” and “katcha”, the sub-components of surrounding landuse are residential building, commercial area, industrial area and vacant land and the sub component of fire management system are fire exist, fire extinguisher, both and none. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. Table 2 shows the weight of each component and sub-component of vulnerablity index.

Table 2: Weights of Component and sub-component of vulnerability index

Component	Sub component	Weight	
		Sub-component	**Component**
Building Type	Pucca	0.2	0.351
	Semi-pucca	0.3	
	Katcha	0.5	
No. of Building Storied	1	0.1	0.067
	2-4	0.3	
	5 or more	0.6	
Distance From Fire Station	4-4.5	0.2	0.102
	4.51-5	0.3	
	5.01-5.5	0.5	
Surrounding Landuse	Residential Area	0.218	0.205
	Commercial Area	0.109	
	Industrial Area	0.051	
	Vacant	0.622	
Distance from hospital	2-2.5	0.4	0.046
	2.51-3	0.6	
Fire management System	Not Present	0.5	0.229
	Fire Exist	0.2	
	Fire Extinguisher	0.2	
	Both	0.1	

Source: Author, 2019

Finally the vulnerability index of a building is calculated by using the given formula.

$$\text{Vulnerability Index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the vulnerability index is classified into three categories, low (0.15-0.233), medium (0.234-0.317) and high (0.318-0.4). According to this classification, 15% buildings are at low level, 60% are at medium level and 25% are at highly vulnerable to fire risk.

3.3 Element at Risk Index

Four components are selected for risk element index.

- Population size
- Population distribution
- Health condition
- Monetary property value.

Sub-components of population distribution are children, elderly and women and the sub-components of health condition are fit, problem in movement and incapable to move. Using the Analytical Hierarchy Process the weight of each of the components and sub-components are determined. 25% buildings are at low level, 35% are at medium level and 40% are at high level. Table 3 shows the weight of each of the component and sub component of element at risk index.

Table 3: Weights of Component and sub-component of risk element index

Component	Sub component	Weight	
		Sub-component	Component
Total Population	0-6	0.1	0.490
	7-12	0.2	
	13-18	0.3	
	19-24	0.4	
Population Distribution	1-2	0.1	0.182
	3-4	0.2	
	5-6	0.3	
	6 or more	0.4	
Health Condition	Fit	0	0.253
	Problem in movement	0.3	
	Incapable to move	0.7	
Property Value	0-1	0.1	0.074
	1-2	0.2	
	2.1-5	0.3	
	5.1 or more	0.4	

Source: Author, 2019

Finally the element at index of a building is calculated by using the given formula.

$$\text{Element at risk index} = \sum_{n=1}^{20} \text{Weight of sub component} * \text{Weight of component}$$

Then the element at risk index is classified into three categories, low (0.140-0.220), medium (0.220-0.300) and high (0.301-0.380).

3.4 Risk Index

To determine the risk index of the specified area risk function is mainly used in this study.

$\text{Risk} = \text{Hazard} * \text{Vulnerability} * \text{Elements at risk}$ (UNNOSA, 2019)

Table 4 shows the risk index and risk level of each of the 20 buildings.

Table 4: Risk Level of 20 selected building

Building No.	Building Coordinate	Hazard Index	Vulnerability Index	Risk Element Index	Risk Index	Hazard Level
1	22°52'00.6"N 89°32'07.2"E	0.146	0.297	0.149	0.0065	Low
2	22°51'56.7"N 89°32'07.5"E	0.185	0.283	0.195	0.0102	Moderate
3	22°51'55.6"N 89°31'58.7"E	0.338	0.39	0.187	0.0247	High
4	22°51'53.2"N 89°32'01.0"E	0.234	0.288	0.111	0.0075	Low
5	22°51'47.4"N 89°31'54.8"E	0.242	0.393	0.176	0.0167	Moderate
6	22°51'44.7"N 89°31'56.7"E	0.318	0.185	0.296	0.0174	Moderate

Building No.	Building Coordinate	Hazard Index	Vulnerability Index	Risk Element Index	Risk Index	Hazard Level
7	22°51'58.3"N 89°31'58.2"E	0.179	0.229	0.213	0.0087	Low
8	22°51'52.8"N 89°31'57.4"E	0.277	0.288	0.149	0.0119	Moderate
Building No.	**Building Coordinate**	**Hazard Index**	**Vulnerability Index**	**Risk Element Index**	**Risk Index**	**Hazard Level**
9	22°51'51.6"N 89°32'06.2"E	0.197	0.31	0.307	0.0187	Moderate
10	22°51'57.0"N 89°32'07.9"E	0.168	0.286	0.119	0.0057	Low
11	22°51'57.4"N 89°32'05.0"E	0.252	0.229	0.195	0.0113	Moderate
12	22°51'51.3"N 89°32'10.3"E	0.297	0.253	0.119	0.0089	Low
13	22°51'47.6"N 89°32'12.6"E	0.263	0.266	0.244	0.0171	Moderate
14	22°51'45.8"N 89°32'09.7"E	0.318	0.253	0.205	0.0165	Moderate
15	22°51'48.2"N 89°32'13.1"E	0.361	0.32	0.303	0.0350	High
16	22°51'58.5"N 89°32'15.8"E	0.336	0.273	0.213	0.0195	Moderate
17	22°51'52.7"N 89°32'25.0"E	0.266	0.307	0.195	0.0159	Moderate
18	22°51'44.9"N 89°32'18.4"E	0.378	0.253	0.327	0.0313	High
19	22°51'47.7"N 89°32'11.4"E	0.309	0.276	0.182	0.0155	Moderate
20	22°51'47.8"N 89°32'07.8"E	0.309	0.319	0.28	0.0276	High

Source: Author, 2019

From the analysis of the collected data the final output showed that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at a extreme risky condition.
Table 5 shows the classification of risk index.

Tabel 5: Classification of Risk Index

Risk Score Range	Risk Level	Number of Buildings	Parcentage
0-0.01	Low	5	25
0.0101-0.02	Moderate	11	55
Above 0.02	Extremly Risky	4	20

Source: Author,2019

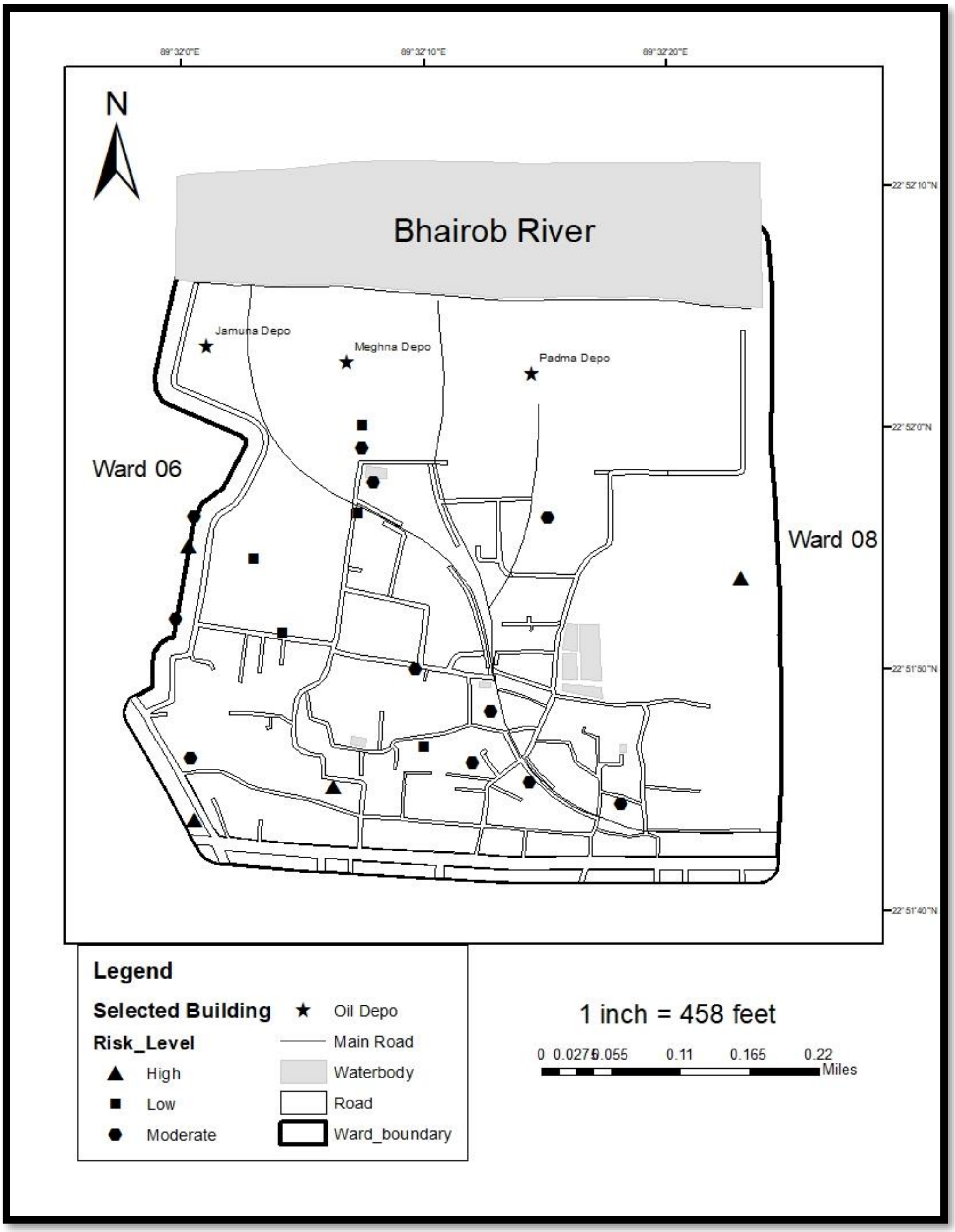

Figure 2: Fire Risk Level of 20 selected Building
(Source: Author, 2019)

4. CONCLUSIONS

The study was focused on determining the risk of the general land-uses next to the risky land-uses in Ward no. 7 of Khulna City. Basically the objective was to display the ignorance towards maintaining the land-use zonal variance. The building located in the study area are under huge risk of fire hazard due to 3 oil depots and 2 power stations in the area. The oil depots creates a huge risk of masive fire explotion wherease the power stations add to the risk.

The factors considered for the fire hazard and risk determination were calculated by AHP method providing specific score and then weightage to the factors. Then finally using the risk function the risk for 20 selected buidings were calculated. Then using the GPS coordinates of the buildings they were pointed out in a map generated with ArcGIS 10.5 to show the current status. The result shows that

- Classifying the building according to the hazard index, 25% buildings are at low level of hazard, 35% are at medium level and 40% are at highly hazardous. The main reason behind this is the ignorance land use zonal variance and lack of concerns about fire hazards.
- Vulnerability index leads to categorizing the buildings into 3 levels of vulnerability, 15% buildings are at low level, 60% are at medium level and 25% are at highly vulnerable to fire risk arising due to lack of governance towards policy formulation and its proper application. Absence of urban planning prior to the development of the area worsens the condition.
- For element at risk 25% buildings are at low level, 35% are at medium level and 40% are at high level. Due to the high population density and most of the people living there are well-off the monetary value of the property at risk are quite high.
- The final output showed that 25% of the buildings are at low risk, 55% of them are at medium and 20% of the buildings are at an extreme risky condition.

As the area is a well established and already developed as a mixed landuse, it is not possible overtime to change or relocate the landuses. Therefore to reduce the risk of fire hazard the precautions and preparedness are the only measures. For precaution the depots and power stations should assure strict rules to avoid triggering a fire hazard and should also have that preparedness to address a fire hazard at a primary stage. The local people needs to be enlightened about the risk and their current vulnerable situation and trained them about their roles and reactions during an accidental fire breakdown.

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PERFORMANCE OF CONCRETE IN FIRE WITH PARTIAL REPLACEMENT OF CEMENT WITH WASTE CERAMIC POWDER

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ABSTRACT

Use of recycled waste materials in production of concrete are getting attention as it enables reuse of resources, facilitates an effective way of waste management and finally, lessens the effect on environment. However, as the fire incident is one of the most recurring disasters in Bangladesh in the last few decades, the performance of concrete produced with any recycled materials should be investigated. In this study, we used waste ceramic powder as a partial replacement of cement in production of concrete and then the performance of the concrete was examined after experiencing a fire incident. Nine beams of size 450×100×100 mm were produced in this work; among them three were produced without mixing any ceramic powder and named as controlled specimens and other six were produced mixing with 20% waste ceramic powder as partial replacement of cement. Among these six beam specimens prepared with ceramic powder, three were burnt in fire and other three were kept unburned. All of the specimens were tested and the flexural strength was determined. The result shows that the flexural strength of the beam specimens was 30% reduced due to the replacement of cement with ceramic powder; the strength of specimens was further 30% reduced due to burning in fire. The outcome of this research will be helpful to the building designers and engineers in designing a fire resistant building and also retrofitting of a structure after an incident of fire.

Keywords: *Fire, Waste ceramic powder, Concrete with recycle waste material, Flexural strength.*

1. INTRODUCTION

Use of waste in concrete is increasing due to recycling of waste materials. Recycled coarse and fine aggregates are being used in the past few decades in concrete. Use of powder as a replacement of cement is also getting attention. Every year a huge amount of ceramic tiles become waste due to damage of tiles during conveying, handling and placing in position (Senthamarai & Devadas Manoharan, 2005). Ceramic and glass waste generation in six major cities of Bangladesh (namely, Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet) was 21075 tonnes in 2005 and it is projected to reach to 128850 tonnes in 2025 (Alamgir and Ahsan, 2007). However, the uses of this waste material give advantages of recycling of the resources which in return contribute to protect the environment. This also provides an effective way to waste management and eventually lessen the cost of construction.

Recently, fire incidents in buildings and factories are frequently occurring hazard in the last few decades in Bangladesh (Department of Disaster Management, 2013). Therefore, there is a growing concern on the fire safety of a building. Though concrete is an incombustible material (Mróz, Hager & Korniejenko, 2016), the strength of a structural element (beam, column etc) can be considerably affected by a fire incident due to high temperature; this may cause in undesirable structural failures (Georgali & Tsakiridis, 2005; Xiao & Konig, 2005; EN 1992-1-2, 2004). The situation may be more dangerous, specially, when this element is made of concrete that contains waste ceramic powder as the ceramic powder does not contribute to the strength of concrete. Therefore, it is necessary to examine the consequence of fire on ceramic based concrete. Therefore, it is necessary to examine the consequence of fire on ceramic based concrete.

In this study, the effect of fire on the flexural strength of concrete, produced by incorporating waste ceramic powder as replacement of cement, has been investigated. The outcome of this study may be beneficial to the engineers, designers, and researchers to take into account the effect of fire during the design period and rehabilitation program after an incident of fire. Furthermore, the use of ceramic waste will reduce the emission of CO_2 due to the replacement of cement by the ceramic waste and resulting contribution to the environment.

2. MATERIALS AND METHODS

2.1 Materials

Locally available materials were used to produce concrete. The Ordinary Portland Cement (OPC) was used as binder, 19 mm downgraded stone chips was used as coarse aggregate, Sylhet sand was used as fine aggregate and ceramic powder as replacement of cement. The properties of materials were determined according to relevant ASTM standards as mentioned in Table 1.

Table 1: Material properties

Materials	Properties	Values	ASTM Standards
Coarse aggregate	Specific gravity (SSD)	2.85	ASTM C 127
	Unit weight, kg/m^3	1570	ASTM C 29
	Maximum size, mm	19	ASTM C 136
Fine aggregate	Specific gravity (SSD)	2.49	ASTM C128
	Fineness modulus	2.76	ASTM C 136
	Unit weight, kg/m^3	1615	ASTM C 29
	Absorption, %	4.55	ASTM C128

Ceramic white tiles were collected from the locally available ceramic waste. Afterwards, the tiles were grinded into powder and passed through #200 sieve (0.075mm). The chemical composition of ceramic waste powder varies according to the type of ceramic tile. The largest proportion of chemical in ceramic waste powder is SiO_2 which is around 65% and the second largest compound is Al_2O_3

which is about 18% (Effting, Folgueras, Güths, & Alarcon, 2018; Morris, Kanali, Gariy & Ronoh, 2018). Other chemical compounds are K_2O, Fe_2O_3, CaO, MgO, Na_2O, TiO_2 and some other compounds in a very minor quantity. The chemical composition of ceramic waste powder is presented in Table 2.

Table 2: Chemical composition of ceramic waste powder (Effting et al., 2010).

Materials	Chemical Composition (%)
SiO_2	63.36
Al_2O_3	18.2
Fe_2O_3	2.77
CaO	1.74
Na_2O	0.34
K_2O	3.87
MnO	0.02
TiO_2	0.80
MgO	2.04
P_2O_2	0.05

2.2 Casting and curing of beam specimens

Concrete mix design was performed according to ACI 211.1. The mix ratio was 1:2.75:3.5 with a mixing water to cement ratio of 0.63. The target cylindrical strength of the concrete was 27.5 MPa (4000 psi) and the achieved strength was 25.94 MPa (3775 psi) which has been considered as satisfactory. Nine rectangular beams of 450×100×100 mm in size were casted as shown in Figure 1.

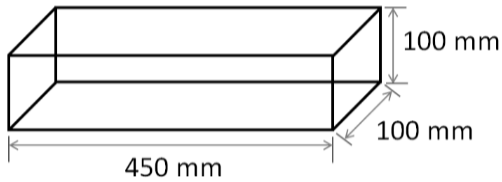

Figure 1: Size of the beam specimen

Three beams were prepared without mixing ceramic powder and six were prepared mixing with 20% ceramic powder as a replacement of cement. The concrete mixing was performed according to ASTM C192 using a standard concrete mixture. At each time of concrete specimen casting, slump was determined and it was within 50 mm. All of the specimens were cured for 28 days. The mixing ratios of concrete are presented in Table 3.

Table 3: Mix ratio of concrete

Sample	Cement	Sand	Stone Chips	w/c ratio	Ceramic Powder	Number of samples
Without ceramic powder (100% cement + 0% ceramic powder)	1	2.75	3.5	0.63	0	3
20% ceramic powder as a replacement of cement (80% cement+ 20% ceramic powder)	0.8	2.75	3.5	0.63	0.2	6

2.3 Burning and cooling of the specimens

A fire chamber of size 2.5 × 1.0 × 0.75 m was prepared to burn the beam specimens. The fire was produced by locally available natural wood. The specimens were burnt in fire for duration of 60 mins and the temperature of fire was 950 °C with a fluctuation of 50 °C at the contact surface of the specimens. The temperature was measured using a thermocouple. After burning, the specimens were kept for natural cooling. In this process, the specimens were cooled for about 24 hours in the air.

2.4 Testing of the specimens

Nine beam specimens were tested and the flexural strength was determined. Among the nine specimens, three specimens (without ceramic powder) tested without burning in fire. Among the other six specimens which were produced with ceramic powder, three were tested without burning in fire and three were tested after burning and cooling. Summary of the testing conditions of the specimens are presented in Table 3.

Table 3: Testing condition of beam specimens

Sample description	**Burning condition**	**Number of specimens**
Without ceramic powder (100% cement + 0% ceramic powder)	Unburnt (Controlled specimen)	3
20% ceramic powder as a replacement of cement (80% cement+ 20% ceramic powder)	Unburnt	3
	Burnt in fire	3

The specimens were tested in the laboratory using third-point loading method according to ASTM C78 and the rupture loads were determined. The experimental setup of the specimens is presented in Figure 2. The flexural strength was calculated by using the following equation –

$$\sigma = \frac{PL}{bd^2} \quad (1)$$

Where, σ = flexural strength, P = failure load, L = loading span length of the beam, b = width of the beam and d = depth of the beam.

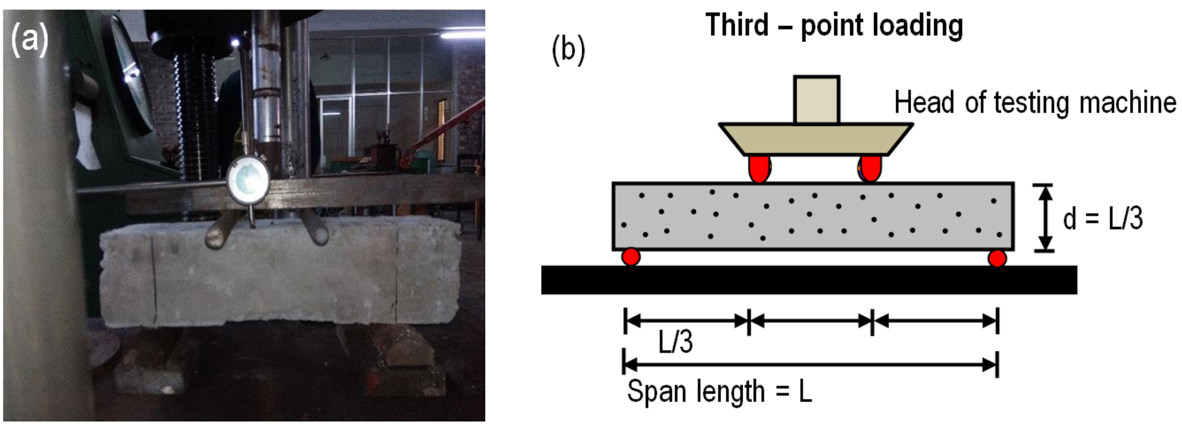

Figure 2: Flexure Test of Concrete by third-point loading method; (a) Photograph of test setup, (b) Schemetic view of test setup.

The weights of the specimens were also measured before and after burning. Afterward, the weight loss due to dehydration from the samples was calculated.

3. RESULTS AND DISCUSSIONS

In this study, nine beams of 450×100×100 mm in size were prepared of which three were controlled specimens produced without using ceramic powder and six were produced with using 20% ceramic powder. Among six specimens with ceramic powder, three beams were burnt in fire and other three were tested without burning in fire. After burning, three specimens were kept for cooling and all of them were tested for flexural strength.

The flexural strength of the specimens was tested at ambient temperature and the results are presented in the Table 4 and a graphical comparison is presented in Figure 3. The flexural strength of the controlled specimen was 5.17 MPa; however, the strength of the specimen was reduced about 30% due to replacement of cement with 20% ceramic powder. The strength of the beam with ceramic powder further 30% reduced due to burning in fire. This reduction of strength was due to the physical damage in the specimens which was caused by spalling and micro-crack in the specimens. The spalling in the specimens was caused due to generation of water pressure developed in the concrete and due to the generation of thermal incompatibility among the different ingredients of concrete. Water was leaking out from the specimens during burning which indicate the escaping of water from the specimens. The failure of the beam due to load is shown in Figure 4. The spalling in the specimens is also shown in Figure 5.

Table 4: Flexural strength of the beam specimens

Type of Specimens	**Test Conditions**	**Sl. no**	**Flexural Strength (MPa)**	**Average flexural Strength (MPa)**	**Reduction of Strength w.r.t. Controlled Specimen**
Without ceramic powder	Unburnt (Controlled specimen)	1	5.04	5.17	
		2	5.4		
		3	5.07		
With ceramic powder	Unburnt	1	3.6	3.55	30
		2	3.6		
		3	3.44		
	Burnt	1	2.04	2.10	60 (40)*
		2	2.1		
		3	2.16		

* 40% reduction of strength w.r.t. unburnt sample prepared with ceramic powder.

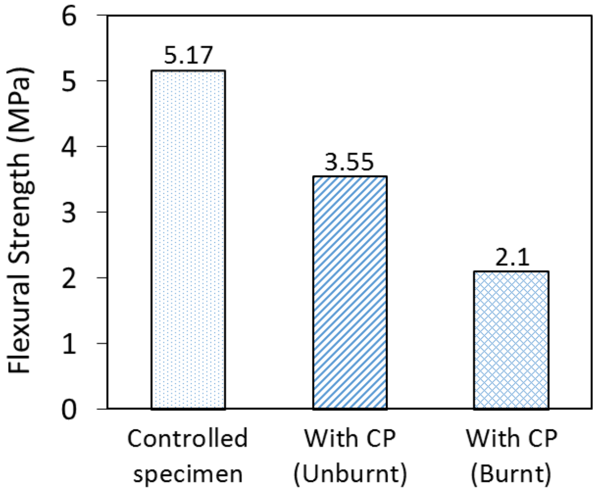

Figure 3: Comparison of flexural strength of beam specimens

Figure 4: Failure of the beam in third-point loading test.

Figure 5: Spalling of concrete in the beam due to burning in fire.

The weight of the sample was reduced due to escaping of water from the specimens. The average loss was about 5%. This loss was resulting from dehydration of the sample. The entrapped water in the specimens was coming out due to high temperature in the sample. Table 5 represents results on the weight loss of the specimens due to burning in fire.

Table 5: Weight loss of specimens due to burning in fire

Sl. No.	**Weight before burning (k**g)	**Weight after burning (k**g)	% Loss of Weight	Avg. % Loss of Weight
1	12.85	12.14	5.53	
2	13.99	13.26	5.29	5.07
3	13.45	12.86	4.40	

4. CONCLUSIONS

In this study, the effect of fire on the flexural strength of concrete prepared with waste ceramic powder as partial replacement of cement has been investigated. Nine beam specimens of 18x4x4 in size were prepared of which three were controlled specimens made without using ceramic powder and six were made with using 20% ceramic powder. Among the six specimens, three were burnt in fire and three were tested without burning. All of the samples were tested and the flexural strengths were determined. The result shows that the flexural strength of the beam specimens was 30% reduced due to replacement of cement with ceramic powder; the strength of specimens was further 30% reduced due to burning in fire. The use of waste ceramic powder as replacement of cement in concrete can be useful for both environmental and economic aspects. However, use of ceramic waste in concrete should be considered by taking into account the effect of fire in the concrete frame. Furthermore, this effect should be considered in case of repairing/refurbishing a building after an incident of fire.

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