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DAMAGE INDICES OF FLOOD DAMAGED BUILDINGS IN PULWAMA DISTRICT OF KASHMIR VALLEY

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ABSTRACT

The damage index of the flood damaged building is a quantitative tool for defining the severity of damage in the building. The numerical damage intensity scale measures the damage phenomena which governs structural degradation or collapse of the building due to the flood waters. The damage intensity scales reflect the contribution of various damages and their severities in all the structural and nonstructural elements of the buildings. The formulated damage index will help in relating the intensities of the damage in various buildings and hence will help in deciding the feasibilities of retrofit or repair in the structure, ifpossible. The formulated damage index is a very realistic tool in order to determine the structural vulnerability of the buildings. The quantification of damage due to flood waters helps in assessing the flood performance of buildings andfeasibility of suitable remedial measures including retrofitting techniques.

Keywords : Damage index; structuralvulnerability; floodperformance; retrofitting techniques;

INTRODUCTION

The state of Jammu and Kashmir suffered disastrous floods across many of its districts in September 2014.The excessive precipitation that had occurred in the month of September 2014 resulted in the excess discharge in river Jhelum .This excessive discharge caused river Jhelum to overflow its bank and the water entered into the residential areas and thus affecting the residential buildings .The flood water that entered the residential buildings caused widespread loss of property and life across Jammu and Kashmir .

This paper refers to the quantification of the damages in buildings caused due to the flood water in Pulwama district of J&K state .The area is located at 32.88°N 74.92°E .It has an average elevation of 1630 m(5350 ft) .The area is 29 km distant from the summer capital (Srinagar) of J&K state.The formulation of damage index started with the overall survey of the area for collection of data for damage analysis. The survey included the various aspects of that area including location of the buildings, the complete details of the house including type of building, material of the building, number of stories of the buildings, the distance of the buildings from the banks of river Jhelum ,the direction through which water entered the residential buildings ,height of water column and most importantly the exact location of the damage present in the building. After the collection of the data from the area the data was analyzed to find the correlation between the damage index and the height of the water column and to find the overall damage index of the building

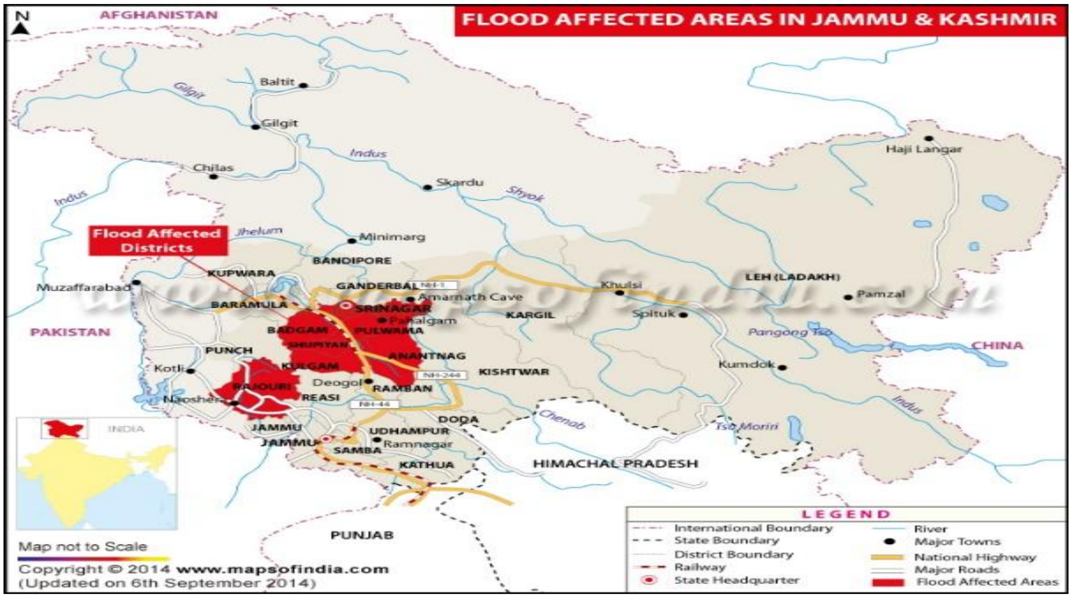

Figure 1: Map showing flood affected areas in jammu and Kashmir

TYPES OF BUILDING:

The different types of buildings that were surveyed are discussed below :

i) Masonary Structures: The majority of the structures that were present in the area are masonary structures. Most of the masonary structures were two storey buildings with the constituent units as bricks and cement mortar .There were few masonary buildings in the mud mortar also.The walls present in the masonary structures were that of loads bearing walls .Most of the masonary structures had strip foundation and stone plinth .The average height of plinth in most of the structures was 2.5 ft.

ii) Framed Structures: The area had few framed structures whose infills walls consist of second class brick work .The most of the framed structures were two storied .The framed structures surveyed were mostly religious places like mosques .The foundation of the framed structures was strip foundations .

DAMAGE ANALYSIS:

The formulation of the damage index of the building involves the following the parameters:

i) Type of damage: The type of damage in masonry structures is referred in IS 13935:2000. The weightage factor assigned to the type of damage for calculating the damage index is taken as 1.

ii) Floor Levels: The floor level of the building represents the location of the damage at different floor levels. The damage in the ground floor in case of floods has got more attention as compared to the damage in the upper stories. The weightage factor assigned to the floor levels for calculating the overall damage index of the building is taken as 0.7.

iii) Material or type of building: The type of building in case of masonry buildings is referred in IS 13935:2000. Apart from type of buildings, the material of the building is also taken into consideration. Accordingly, the weightage factor assigned to material and type of building is taken as 0.9.

iv) Location of the damage: Itspecifies the location of damage in the building. The location of the damage helps in finding the influence of damage on other related structural and nonstructural elements. The weightage factor assigned to the location of the damage for calculating the overall damage index of the building is taken as 0.9.

v) Age of the building: The age of the building determines the vulnerability of the damage due to the flood waters. Accordingly, buildings which are quite old are very vulnerable to the damage because of degradation of material stiffness and overall loss of the strength and stiffness of the building. Theweightage factor assigned to the age of the building for calculating the damage index of the building is taken as 0.7.

The weightage factors assigned to different parameters of the damage are shown in Table 1.

Table 1: Weightage factors to damage index for different parameters of damage in the building

Parameters of the damage	Overall Weightage factor	Sub -type	Weightage Factor
Type of the damage	1	G1	0.4
		G2	0.6
		G3	0.8
		G4	0.9
		G5	1
Floor level	0.7	Ground floor	1
		First floor	0.9
		Second floor	0.8
Material or type of foundation	0.9	Concrete	0.7
		Bricks with cement mortar	0.8
		Bricks with mud mortar	1
Location of the damage	0.9	Beams and columns (Framed Structures)	1
		Walls (partition walls)	0.5
		Walls (load bearing structures)	0.9
		Plinth ,lintel and slab	0.8
Age of the building	0.7	<20 years	0.6
		20-40 years	0.7
		40-60 years	0.8
		60-80 years	0.9
		80-100 years	1

CALCULATION OF DAMAGE INDEX:

The final damage index of the building is calculated by incorporating all the parameters of the damage and their corresponding weightage factors and are converted into one numerical value through simple arithmetic calculations. The calculated damage index are related with the height of water column and thus efforts have been made to find the relation between height of water column and severity of damage so that the data could be used for flood vulnerability studies of the area in the future.The calculated damage index are compared and thus conclusions are drawn about the intensity of the damage and the selection of retrofitting or repair techniques of the buildings .

For calculating the damage index of the building large set of data have been taken from field surveys .The data included the various details of the building like the number of stories ,material used in the structure, type of the structure ,direction through which water entered into the house etc.The details of the buildings are given in the tabular form.The study also included the precise study of location and type of crack for calculating accurate damage index factor .

BUILDING 1:

Table 2 shows the details of the building collected from the field survey.

Distance of house from Jhelum bank	237.18m
Direction through which water entered the house	North side
Nature of flow	Highly turbulent
Height of water column above plinth	10 ft
No. of storeys	2
Material used in the structure	Bricks with mud mortar
Type of structure	Load bearing
Wall thickness	13”
Height of plinth	2.5 ft
Height of building	20.5 ft
Size of openings	Door(3’×6’) windows (5’×4’)
Age of structure	25 years

Figure 2: photograph of building (left) and the location of the building on the google map

DAMAGE INBUILDING 1 : The damage in the building has been studied exclusively for the calculation of damage index. The building has cracks distributed widely in ground floor as well as in first floor .The cracks in the buildings range from G1 to G5(IS 13935:2000).The ground floor has four predominant cracks.Crack 1(G2) is a vertical crack present in the wall of the room of ground story. Crack 2(G2) is the crack present in the interface of door and wall and is also a vertical crack .Crack 3 (G5) is diagonal crack present in the load bearing wall of first floor .Similarly crack4 (G2) is the crack present in the lintel level of first floor Since the building is load bearing structure there were no beams and columns present in the structure. Also the floor of the building consist of wooden floor and there was no concrete slab present in the building. Crack 5 (G4) is the diagonal crack present in the walls of first floor and crack 6(G2) is the crack present at the floor level of the ground floor.

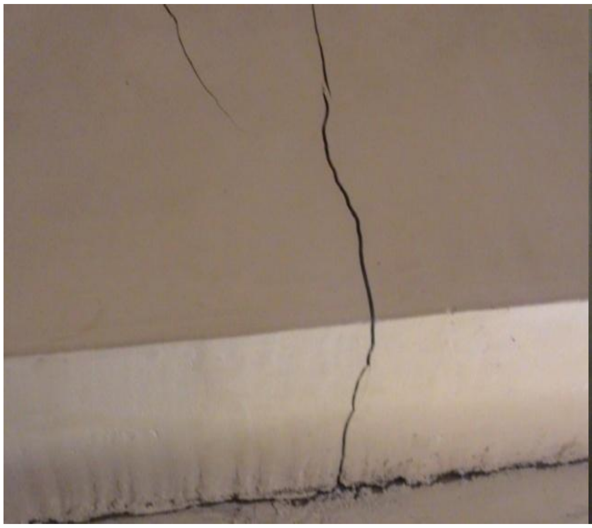
Figure 3: Crack 1 (Ground Floor)

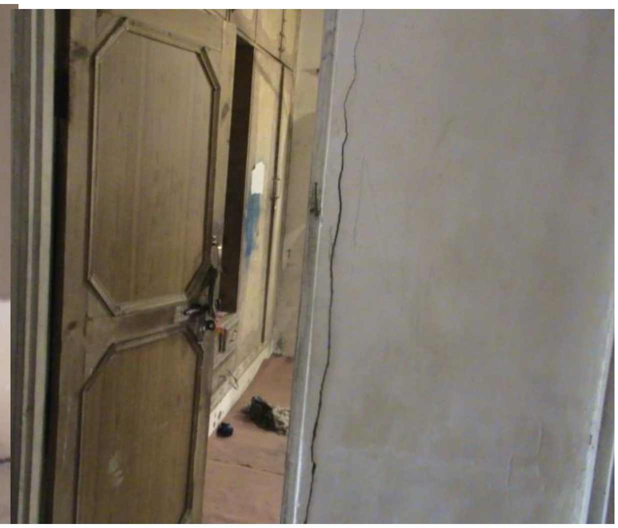
Figure 4: Crack 2(Ground floor)


Figure 5: Crack 3 (First Floor)


Figure 6: Crack 4(First Floor)


Figure 7: Crack 4(first Floor)


Figure 8: Crack 5(Ground Floor)

FORMULATION OF DAMAGE INDEX: The damage index of the building is calculated in Table 3

Table 3: calculation of damage index of building 1

DAMAGE	TYPE OF DAMAGE	FLOOR LEVEL	MATERIAL OF THE BUILDING	LOCATION OF THE DAMAGE	AGE OF THE BUILDING	Damage Index
Overall weightage Factor	**(1)**	**(0.7)**	**(0.9)**	**(0.9)**	**(0.7)**	
CRACK 1	0.6	1	1	0.9	0.7	(1×0.6) × (0.7×1) × (0.9×1) × (0.9×0.9) × (0.7×0.7) **=0.150**
CRACK 2	0.6	1	1	0.8	0.7	(1×0.6) × (0.7×1) × (0.9×1) × (0.9×0.8) × (0.7×0.7)**= 0.133**
CRACK 3	1	0.9	1	0.9	0.7	(1×1)×(0.7×0.9)×(0.9×1)× (0.9×0.9)×(0.7×0.7) **=0.225**
CRACK 4	0.6	0.9	1	0.8	0.7	(1×0.6) × (0.7×0.9) × (0.9×1)×(0.9×0.8)× (0.7×0.7) **=0.120**
CRACK 5	0.9	0.9	1	0.9	0.7	(0.9×1) × (0.7×0.9) × (0.9×1) × (0.9×0.9) × (0.7×0.7) **=0.202**
CRACK 6	0.6	1	1	0.8	0.7	(1×0.6) × (0.7×1) × (0.9×1) × (0.9×0.8) × (0.7×0.7) **=0.133**
TOTAL DAMAGE INDEX OF THE BUILDING						0.150+0.133+0.225+0.120 +0.202+0.133 =**0.963**

BUILDING NO.2:

The building 2 surveyed for damage analysis was a local mosque which was situated very near to the Jhelum river. The distance of the building from the bank of Jhelum river was 152.44 m.The nature of flow of flood water was highly turbulent and the maximum damage inflicted on the building was due to hydrodynamic and impact loads .The building consisted of beams, column and brick masonary. The details of the building collected from field survey is shown in table 4.

Table 4 : Details of the building collected from the field survey

Distance of mosque from Jhelum bank	152.44m
Direction through which water entered the house	North side
Nature of flow	Highly turbulent
Height of water column above plinth	6 ft
No. of storeys	2
Material used in the structure	Cement concrete
Type of structure	Framed structure
Wall thickness	13”
Height of plinth	3 ft
Height of building	20 ft
Size of openings	Door(5’×7’) windows (3’×4’)
Age of structure	10 years

Figure 9:Photograph of building 2 (left) and its location of the building on google map

DAMAGE IN THE BUILDING:

Due to the high turbulence of the water one of the walls of the structure was completely raised to the ground .Since the wall was sandwiched between beams and columns and hence beams and columns also failed (figure 10).The complete failure of the wall forced the beams and slab to come down and hence a portion of the slab came down.The infill brick masonary also developed diagonal cracks (Figure 11) of type G4.The beams of the building suffered heavy damage and the damage type exceeded G5(figure 12).The brick work of first storey was completely damaged (figure 13).The lintel of the groung floor suffered the cracks of type G5.The beam column junction of the ground floor suffered massive damage and the junction reinforcement came out . .

Figure 10: Damage 1

Figure 11:Damage 2

Figure 12: Damage 3

Figure 13:Damage 4

CALCULATION OF DAMAGE INDEX:

The damage index of the building 2 is calculated in Table 5

Table 5:Calculation of damage inex of building 2

DAMAGE	TYPE OF DAMAGE	FLOOR LEVEL	MATERIAL OF THE BUILDING	LOCATION OF THE DAMAGE	AGE OF THE BUILDING	Damage Index
Overall weightage Factor	**(1)**	**(0.7)**	**(0.9)**	**(0.9)**	**(0.7)**	
Damage 1	1	1	0.8	1	0.6	(1×1) × (0.7×1) × (0.9×0.8) × (0.9×1) × (0.7×0.6) =**0.190**
Damage 2	0.9	1	0.8	0.9	0.6	(1×0.9) × (0.7×1) × (0.9×0.8) × (0.9×0.9) × (0.7×0.6)**= 0.154**
Damage 3	1	1	0.8	1	0.6	(1×1)×(0.7×1)×(0.9×0.8)× (0.9×1)×(0.7×0.6) **=0.190**
Damage 4	1	0.9	0.8	0.9	0.6	(1×1) × (0.7×0.9) × (0.9×0.8)×(0.9×0.9)× (0.7×0.6) =**0.154**
Damage 5	1	0.9	0.8	0.8	0.6	(1×1) × (0.7×0.9) × (0.9×0.8) × (0.9×0.8) × (0.7×0.6) =**0.137**
Damage 6	1	1	0.8	1	0.6	(1×1) × (0.7×1) × (0.9×0.8) × (0.9×1) × (0.7×0.6) =**0.190**
TOTAL DAMAGE INDEX OF THE BUILDING						0.190+0.154+0.190+0.154 +0.137+0.190=**1.015**

SUMMMARY:

The damage index of the building 1 is**0.963** and that of building 2 is**1.015** .From the damage index values it can be inferred that the building 2 has suffered more damage than building 1.The height of the water column above the plinth is 6ft in building 2 while as the height of water column above plinth is 10 ft in building 1 .The reason for maximum damage in building 2 inspite of having less height of water column is attributed to hydrodynamic and impact loads ,while as in case of building 1 the damage is attributed to hydrostatic action of flood water The damage index of large number of buildings can be calculated by the same procedure and then correlation between height of the water column and damage index can be drawn.From the above studies it can be also infered that the building 1 has scope of retrofit or repair as compared to building 2 which has no scope for repair or retrofit.

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