Numerical study on the damage behavior of concrete target influenced by penetration velocity and target properties

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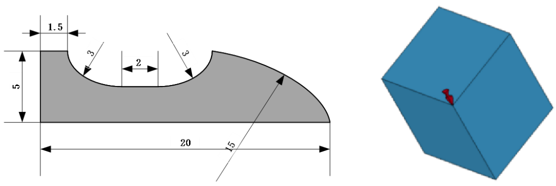
Abstract

The influence of initial penetration velocity and target properties on the damage behavior of concrete target by kinetic energy (KE) projectiles are studied numerically. Numerical models of penetration at different velocities were established, the failure of concrete and the law of the impact at different initial velocities ranging from 950 m/s to 1500 m/s on the damage behavior of concrete target is obtained. Damage process of concrete target slabs with different strengths and thicknesses under various impact load was carried out and the relationships between the damage behavior and the target strength ranging from 35 MPa to 95 MPa and the thickness ranging from 1 m to 2 m were obtained. Combination with the experiment results demonstrates that, the descent rate of the initial velocities increase as the initial velocities were improved. The higher the strength of the target, the less the residual velocity decrease caused by increasing the strength of the target. Under the condition of the same thickness increase amplitude, higher totally thickness of the targets results in greater penetration resistance. Furthermore, the overload peak value and the oscillation period of the impact load are positively related to the initial velocity and target thickness. With the increase of penetration depth, the impact load presents a first dramatic increase, then gradual decrease trend with obvious oscillations.

Introduction

The damge behavior of concrete under the kinetic energy projectile penetration has always been a key research object in the field of national defense. However, due to the multidisciplinary aspects of weapons, materials, physics, mechanics, and the complexity of concrete materials, the research has become very important. Therefore, the research on the kinetic energy projectile penetrating the concrete target has practical military needs and important scientific research significance.Both the penetration velocity and the parameters of the concrete target have an important influence on the damge behavior of the concrete.

In this paper, numerical simulation methods are used to study the damage of the high-initial velocity kinetic energy projectile penetrating the thick concrete target to obtain the penetration velocity and the target parameters from the influence of penetration performance. The law of the influence of penetration velocity and target parameters on the damage behavior of concrete was obtained.



Geometric model of kinetic energy projectile and penetration model.

Methods

The material of the projectile is high-strength steel (PCrNi3MoV steel), which is an isotropic non-linear hardening material. A bilinear follow-up hardening model is adopted which considers the effect of strain rate on the strength of the material and also considers the failure strain. The effect of the model is suitable for the study of kinetic energy projectile penetration into concrete.The concrete material adopts the HJC constitutive model. This model considers the compaction state of the material and accumulates material damage. It can simulate large strain, large strain rate of the material.

The HJC constitutive model is suitable for describing compression failure of concrete materials, but lacks the description of tensile failure. The introduction of the erosion failure criterion can improve this problem in the penetration problem of kinetic energy projectile.

ρ(g/cm3)	G(100GPa)	A	B	C	N	f_c (100GPa)
2.44	0.1486	0.79	1.60	0.007	0.61	0.00048
T(100GPa)	ε_0	ε_{min}	ε_{max}	P_c (100GPa)	u_c	p_l
4.0E-5	1.0E-6	0.01	7.00	0.00016	0.001	0.008
u_l	D_1	D_2	K_1	K_2	K_3	FS
0.10	0.04	1.00	0.85	-1.71	2.08	0.4

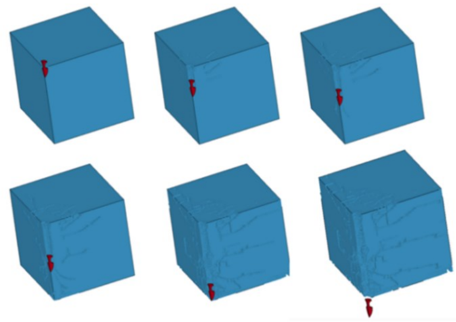
The parameters of the HJC model.

MID	EXCL	MXPRES	MNEPS	EFFEPS	VOLEPS	NUMFIP	NCS
2	1234	—	—	—	—	—	—
MNPRES	SIGP1	SIGVM	MXEPS	EPSSH	SIGTH	IMPULSE	FAILTM
-4E-5	1234	1234	0.08	1234	1234	1234	1234

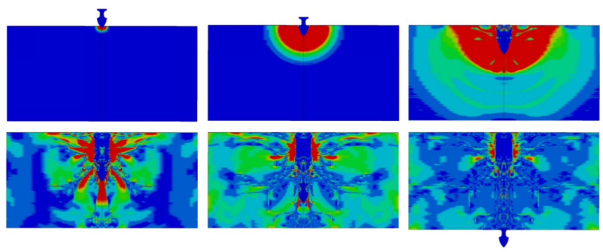
The parameters of erosion failure.

Results

After the projectile comes into contact with the target surface, severe collision, friction, and shear occur to form an open pit area. After the projectile enters the concrete, it continues to squeeze and shear the concrete at the front of the projectile while crushing the concrete around the projectile at high speed. A penetration channel is formed, the diameter of the penetration channel is slightly larger than the diameter of the projectile. During the penetration process, cracks caused by failure form and extend around the target. After the stress shock wave reaches the free end of the rear of the target plate, it forms a tensile wave. The rear of the target plate formed an inverted conical plug block.

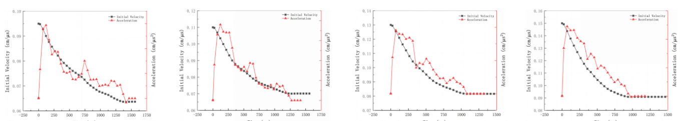


The simulation of the penetration process.



Stress propagation during penetration.

At once the projectile contacts with the concrete target, a stress jump will be formed on the concrete surface, and a red stress shock wave will be transmitted around the target . During the penetration, some units will be deleted and some units will be crowded out, then the stress is redistributed. It can be seen from the figure that the stress is propagated to the free surface of the target back and reflected internally, which superimposes with the stress wave to form a blue negative pressure tensile wave, which makes the area near the target back become a strong tensile zone, resulting in tensile failure of the rear area of the concrete target and spalling. After the projectile reaches the crack zone, it will collide and squeeze with the concrete block that has been stretched out, resulting in the redistribution of stress, and the crack will extend around to the back of the target, forming an inverted conical plug block.



950 m/s 1100 m/s 1300 m/s 1500 m/s

It can be seen that the time-history curve of the residual velocity under different initial velocities is a smooth curve, indicating that the impact of the initial velocity of penetration on the penetration performance is similar. The residual velocity decreases rapidly when the penetration velocity is large in the early stage, then decreases with the penetration velocity, and then decreases more and more slowly in the later stage, and finally penetrates the concrete target.It indicates that the penetration resistance of concrete target is enhanced with the increase of the initial velocity.

Conclusion

The overload peak value of the projectile and the damage degree increase along with the initial velocity. The residual velocity decreases as the strength of the target increases. The greater the strength of the target, the less the decrease of the residual velocity caused by increasing the strength of the target. The residual velocity decreases with the increase of the thickness of the concrete target. The peak overload of the projectile with different thickness concrete target is almost equal, and the overload oscillation period increases with the thickness. With the increase of the penetration depth, the overload of the projectile continues to decrease. Under the same thickness interval, the anti-penetration performance of the concrete target improves as the thickness of the target increases.